[148.]

Royal Observatory, Greenwich, London, S.E.,

1859, May 12

SIR,

I have the honour to inform you that 1 copy of the Report of Professor C. P. Smyth on the Teneriffe Astronomical Experiment of 1856, presented to the Bodleian Library, Oxford, by authority of the Lords Commissioners of the Admiralty, has been forwarded by post to your Address

I request the favor of an acknowledgment of receipt.

I have the honor to be,

SIR,

Your very obedient Servant,

G B Airy

To the Librarian
Bodleian Library
Oxford

REPORT

ON THE

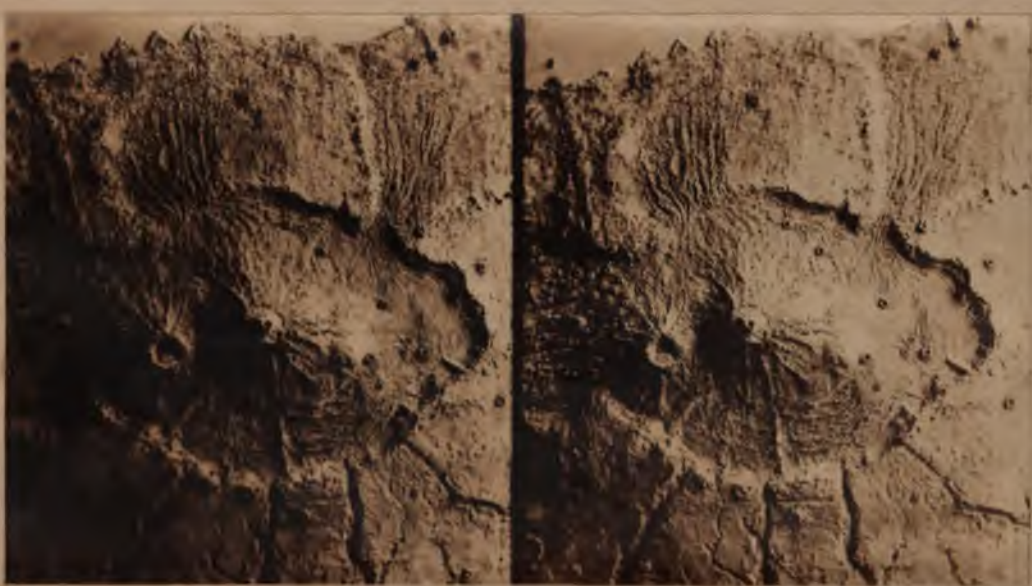
TENERIFFE ASTRONOMICAL EXPERIMENT OF 1856,

ADDRESSED TO THE LORDS COMMISSIONERS OF THE ADMIRALTY,

BY

PROF. C. PIAZZI SMYTH, F.R.SS. L. & E., F.R.A.S., AND

H. M. ASTRONOMER FOR SCOTLAND.



C. P. S. Phot. J. P. S. Fr.

STEREOSCOPIC MAP OF THE PEAK AND GREAT CRATER OF TENERIFFE.
From a Model by J. Nasmyth, Esq., C.E., founded on data procured by the Expedition.

LONDON AND EDINBURGH:

PRINTED BY RICHARD TAYLOR AND WILLIAM FRANCIS, RED LION COURT, FLEET STREET, LONDON,
AND NEILL AND COMPANY, HIGH STREET, EDINBURGH.

1858.

CONTENTS.

ILLUSTRATIONS.

PREFACE.

THE following pages represent Books 7, 8, and 9 of the MS. "Teneriffe Report of 1856," and have been very liberally printed at the expense of the Lords Commissioners of the Admiralty; through the medium of the Royal Society of London from pp. 463 to 534, with Plates 30 to 39; and through the intervention of G. B. AIRY Esq., Astronomer Royal, from page 535 to the conclusion.

The whole of the MS., had been communicated by their Lordships to the above Society on the 2d June 1857, in expectation of its being immediately published in the "Philosophical Transactions;" but after a period of ten months, the Council objected to undertake more than Books 7 and 8, and did not conclude the printing of these two until the end of January 1859. The extra copies struck off for the Admiralty (under previous arrangement) being delivered a few days afterwards to the Astronomer Royal, were completed by the addition of the remaining Book.

February 1859.

ERRATA.

Page 557, col. 6 of table, 3d reference, *for* p. 66 *read* p. 531.

Plate 30, *for* FUERTEVENTURA *read* FUERTAVENTURA.

Plate 33, the upper figure of Jupiter is printed too heavy by one-third, and the lower figure by one-half, the amount of shade expressed.

ASTRONOMICAL EXPERIMENT

ON

THE PEAK OF TENERIFFE,

CARRIED OUT

UNDER THE SANCTION OF THE LORDS COMMISSIONERS OF THE ADMIRALTY.

BY

PROFESSOR C. PIAZZI SMYTH.

From the PHILOSOPHICAL TRANSACTIONS.—PART II. FOR 1858.

LONDON:

PRINTED BY TAYLOR AND FRANCIS, RED LION COURT, FLEET STREET.

1858.

XXV. *Astronomical Experiment on the Peak of Teneriffe, carried out under the sanction of the Lords Commissioners of the Admiralty. By Professor* C. PIAZZI SMYTH. *Communicated by* G. B. AIRY, *Esq., Astronomer Royal.*

Received June 2,—Read June 18, 1857.

CHAPTER I.

INTRODUCTORY.

(1.) *Origin and Objects.*

THE principal object of the experiment on Teneriffe in the summer of 1856, was to ascertain how much astronomical observation can be benefited, by eliminating the lower third or fourth part of the atmosphere. That the amount of such improvement would be large and form a desirable boon to practical astronomy, appears to have been expected by Sir ISAAC NEWTON; for in his 'Optics' he expressly says, "They (telescopes) cannot be so formed as to take away that confusion of rays which arises from the tremors of the atmosphere. The only remedy is a most serene and quiet air, such as may perhaps be found on the tops of the highest mountains above the grosser clouds."

After having enjoyed some slight practical experience of the method so recommended, during the remeasurement of LA CAILLE's Southern Arc of the Meridian under Mr. MACLEAR, its further prosecution was brought prominently to my attention by the peculiar position of the Edinburgh Observatory. Accordingly, in November 1852, I had the honour of presenting to the Board of Visitors, under the Presidency of the Right Hon. Lord RUTHERFURD, a scheme for realizing NEWTON's idea through means of a summer expedition to the Peak of Teneriffe; where there appeared a hope that telescopes might be elevated more than 10,000 feet above the level of the sea, with greater facilities of every sort, than on any other known mountain. The same project was also brought before Section A. of the British Association, three years later.

In the autumn of 1855, a copy of the Edinburgh Observatory Report reached the hands of R. STEPHENSON, Esq., M.P.; and he found its indications to agree so well with his own experience in early life on South American Cordilleras, that, though we were entirely unacquainted, he very kindly sent me, through a mutual friend, an offer of a passage to Teneriffe in his yacht 'Titania.' Circumstances, however, prevented my profiting by his kindness on that occasion.

Finally, in the spring of 1856, the Astronomer Royal, G. B. AIRY, Esq., having himself engaged in some special astronomical inquiries, where success was rendered impossible by interference of the atmosphere; and having become convinced of the per-

fect practicability of making an experiment on the Peak of Teneriffe,—laid a statement to that effect before the First Lord of the Admiralty, the Right Honourable Sir Charles Wood.

That Minister instantly saw the importance of the proposition, and entering most warmly and liberally into it, at once agreed to furnish such funds as would enable me to proceed immediately to Teneriffe; and, with due permission from the Spanish authorities, make trial of the capabilities of the mountain. The first estimate amounted to £300; but so noble a view did the Admiralty take of the matter, that they inquired, through their Hydrographer (Captain Washington), if £300 was not too small a sum for the efficient performance of the service. Having in the meantime received good reasons from Mr. Airy for taking out a larger telescope than I had at first contemplated, I sent in a second estimate for £500, and it was immediately authorized.

The spring being now well advanced (May the 2nd), there was but short time to prepare; and it is here proper again to express my obligations to the Admiralty, who left me unfettered by any instructions, except the very reasonable one of not exceeding the grant. The preparations therefore went on rapidly in May and June.

Meanwhile the Admiralty wrote to the Royal Society, the Royal Astronomical Society, the British Association, Sir John Herschel, Mr. Airy, and the Director of the Ordnance Survey, informing them of the authorization, and inquiring if they had any suggestions to offer.

These several parties highly approved of the measure, but sent in propositions for so much additional work, that the whole scale of the mission, its time for preparation, and for execution, its materials, men, and money, would have had to be greatly extended to include them all. Many reasons, however, dictated the propriety of keeping to the original idea, of making the experiment for the summer of 1856 a tentative one merely.

A capability nevertheless of attending to many of the very important suggestions thus made, and without exceeding the Admiralty allowance, was acquired before long through the liberal loans made by private individuals. The number and value of these are so interesting a proof of the estimation in which the undertaking, as an attempt to solve an important problem in practical astronomy, was viewed by the scientific men of Great Britain, that they may well be entered here.

(1.) Actinometer, Magnetometer, two Radiation thermometers, Electrometer, Spectrum apparatus, and Polarimeter. By G. B. Airy, Astronomer Royal. (2.) Equatorial instrument; the telescope 11 feet in focal length, and $7\frac{1}{4}$ inches aperture with clock motion. By H. L. Pattinson, Esq., of Newcastle-on-Tyne. (3.) A Quartz train for spectrum observations. By Professor G. G. Stokes. (4.) Mountain Barometer, and six thermometers. By Dr. Lee of Hartwell. (5.) Mountain Barometer, and four thermometers. By J. Adie, Esq., of Edinburgh. (6.) A Thermo-multiplier. By J. P. Gassiot, Esq., F.R.S. (7.) Four barometers, twelve thermometers and hydrometers compared at the Kew Observatory, with blank books and maps. By Admiral FitzRoy on the part of the Board of Trade. (8.) Four Chronometers. By the Hydro-

grapher to the Admiralty, Captain WASHINGTON. (9.) Double Sextant. By Admiral BEECHEY. (10.) Polarization apparatus. By the Rev. BADEN POWELL. (11.) Plane speculum and apparatus to facilitate the observation of red prominences round the sun. By J. NASMYTH, C.E. (12.) Eyepieces and adaptations to Equatorial. By T. COOKE, Esq., of York. (13.) Lastly, by ROBERT STEPHENSON, Esq., M.P., was made the loan of his yacht 'Titania' of 140 tons, and with a crew of sixteen men, for the voyage out and home, and during the whole period of the experiment.

In addition to the above instruments, I took from the Edinburgh Observatory the 5-foot equatorial, presented some years since by the late Rev. R. SHEEPSHANKS; and received much kind assistance from Admirals MANNERS and W. H. SMYTH, Sir DAVID BREWSTER, Mr. WELSH of Kew, and J. J. FORRESTER, Esq.; while in their official capacities, Lord CLARENDON, J. MURRAY, the British Consul in Santa Cruz, and A. GOODALL, acting Vice-Consul in Orotava, rendered important services; and I have to mention with thanks my obligations to the Spanish authorities, to L. HAMILTON, Esq., C. SMITH, Esq., Don FRANCISCO AGUILAR, Don MARTIN RODRIGUEZ, Mr. ANDREW CARPENTER, and Herr KREITZ, all of Teneriffe; as well as to the Brazilian Steam Packet Company.

(2.) *Instructions and Suggestions.*

The leading object given to me was, as already stated, to ascertain how much astronomical observation can be benefited by raising telescopes high into the air, and so enabling an observer to look at the celestial bodies through a less depth of atmosphere than they could from any of the ordinary observatories, established as they are, at or near the level of the sea.

If we could rise high enough above the clouds, not only should we at once have clear in place of cloudy skies,—no mean advantage in itself, as enabling us to increase the number of observations,—but their quality, a matter of far higher importance, would be advanced at the same time. For in proportion as the atmosphere itself is overpassed, so are the irregularities in its action on rays of light passing through it; and these irregularities are precisely what form the chief bar to accuracy of instrumental measure, and to certainty of telescopic vision.

On the other hand exist the drawbacks, that on a high mountain it may be difficult to drag up the largest class of telescope, and impossible to build a large observatory; and though the air be thin and transparent, it may be in such a state of motion as to be prejudicial to the steadiness of instruments; or again, the mountain top may be always enveloped in a local cloud. The exact value of these objections was only to be found by actual trial; and that, if they should be overcome, a new gateway would be opened up in the paths of science, not astronomical only, but of many allied subjects, may be gathered from the very important mass of suggestions sent into the Admiralty by their several referees, as below. They show indeed, what might be expected from a good mountain station, well worked for a series of years, rather than what a preliminary experimental trial on a small scale would be able to accomplish in a few weeks.

I.—*Letter from* G. B. AIRY, *Astronomer Royal, to the Secretary of the Admiralty, dated 13th May*, 1856.

"SIR,—I have the honour to acknowledge your letter of the 2nd instant, acquainting me with the sanction of the Lords Commissioners of the Admiralty to a grant of £500 to Professor PIAZZI SMYTH for defraying the expenses of an astronomical visit to the Peak of Teneriffe, and requesting me to communicate any suggestions for the due carrying out of this project, which may occur to me.

"2. In reply, I would first submit to My Lords, that though it is desirable that some document of the character of Instructions should be issued, as indicating their Lordships' general understanding of the grounds on which they have sanctioned this appropriation of public money, yet on the other hand it is most desirable that the several heads should be so lightly stated, as to leave Professor SMYTH in the most absolute freedom as to his general course of action.

"3. First, I would state as the recommendation of their Lordships, that Professor SMYTH should consider the object of his expedition to be not so much to obtain specific and determinate results, as to ascertain what may be done, or what may be expected in future expeditions to places under the same atmospheric circumstances. The main thing is, to discover how much astronomical observations may be benefited by the removal of the injurious influence of the lower third part of the atmosphere. At the same time, there are some specific observations, requiring little time, and naturally falling in with the general series, which it is well to mention by name.

"4. Among these, the first beyond all doubt is to endeavour to ascertain whether the red prominences which have been seen on occasions of total eclipses of the sun, and which seem to be connected with the sun's body, can be seen upon the uneclipsed sun, when the atmosphere is so rare and so pure that the diffused light in the proximity of the sun's disk becomes practically insensible.

"5. It is very desirable that careful observations should be made on the zodiacal light, and that these should be continued through all hours of the night, and especially about midnight. Observations lately published have led several persons to suppose that the matter whose illumination exhibits the zodiacal light surrounds not the sun, but the earth; and this could probably be definitively settled on the Peak of Teneriffe.

"6. The scrutiny of the appearances of some double stars and nebulæ, and more especially that of the disks of the moon, the planets, and their satellites, obviously presents itself as an important object. Perhaps, however, it is to be desired that the observations should be so framed as to determine what can be done, rather than at present to carry out any laborious series of special observations.

"7. In the related subject of optics, it is to be desired that measures of the polarization of the light and determinations of the plane of polarization, be made in different parts of the sky, and be compared with similar observations made at the bottom of the mountain.

"8. It is also desirable that FRAUNHOFER'S spectral lines should be observed with various elevations of the sun, and in different parts of the sky, and should be compared with observations made at the bottom of the mountain.

"9. The determination of the comparative horizontal intensity of terrestrial magnetism above and below would be useful, unless the magnetism of the mountain should vitiate all magnetic observations.

"10. A few observations of temperature at various times, radiation, moisture, and electricity, are to be recommended. These, like all those last mentioned, should be comparative.

"11. Advantage may be taken of a residence on the mountain for making such an examination as will decide whether the mountain is a favourable one for experiments on the attraction of mountains. It will be borne in mind, that if not favourable for determining the attraction north and south by means of the zenith-sector, it may be favourable for determining the attraction east and west by means of the transit instrument, provided that it is possible to carry a galvanic communication over the mountain.

"12. If the general tenor of the observations, which Professor SMYTH shall be able to make, leads him to think that material advantage may be produced to astronomy by the establishment at some future time of an observatory of more permanent character at a great elevation, the mountain may be examined for the purpose of deciding whether it is upon the whole a favourable place for such an establishment, and what point of the mountain will prove practically the best locality.

"13. In submitting to their Lordships these drafts of suggestions, I would beg leave again to refer to the opinion which I have expressed in article 2, that it is desirable that Professor SMYTH be fettered as little as possible by instructions.

"I have the honour to be, Sir,

"Your very obedient Servant,

(Signed) "G. B. AIRY.

"1856, May 29th.

"*Additional Suggestions for Professor* C. P. SMYTH, *by* G. B. AIRY.

"Observations for the height and duration of twilight.
Dip of the sea-horizon.
Refractions near the horizon.
Solar radiation."

II.—*Letter from Sir* JOHN HERSCHEL *to the Secretary of the Admiralty, dated Collingwood,* 5*th May,* 1856.

"SIR,—In reply to your letter of the 2nd inst., informing me that the Lords Commissioners of the Admiralty have been pleased to sanction a grant of £500 to meet the

expenses of an astronomical expedition to the Peak of Teneriffe, to be undertaken by Professor SMYTH of Edinburgh, and that their Lordships wish me to furnish them with any suggestions I may have to offer for the better carrying out the project;—

"1st. I have to state, that I consider the opportunity a very valuable one for obtaining an extensive and normal series of comparative actinometric observations, made *simultaneously* (strictly so) on the summit of the mountain and at the level of the sea, with actinometers provided with interior thermometers (not mercurial). These instruments, and the mode of using them, are fully described in the section on Meteorology, and forming part of the 'Manual of Scientific Inquiry' published by authority of their Lordships in 1849; the object being the determination of the proportion of the solar heat absorbed by the atmosphere between the two limits of altitude. Should circumstances permit, an intermediate station, about half-way up the mountain, would afford valuable supplementary observations. Such observations, taken at the time of the sun being vertical, would be very precious, but the series should be extended to every altitude of the sun down to the horizon.

"2nd. It has been stated, that at a place considerably lower than the actual summit of the Peak, there occur caverns on the mountain side, in which, though beneath the limit of perpetual snow proper to those latitudes, the temperature is always below the freezing-point. The fact (which is not without analogous ones elsewhere) should be inquired into, accurate observations made, and the concomitant circumstances carefully recorded.

"3rd. The opportunity will of course not be lost of ascertaining by comparative observations, with one and the same telescope, in England, at Orotava, and on the summit of the Peak, what degree of advantage, in point of optical performance, is obtained by change of climate, and by ascent into a clearer and rarer atmosphere. The selection of proper objects of comparison, such as nebulæ, clusters, double stars, &c., must be left to the observer's judgment.

"4th. The spots of the sun will probably be observed to very much greater advantage at so elevated a station, and by the aid of Mr. DAWES' eyepiece, their physical peculiarities may there be examined with every prospect of obtaining some distinctly new information. There, too, if anywhere, it may be possible, by careful management, to obtain a sight of the red protuberances from the sun's limb, which on the plains can never be seen but on the occasion of a total eclipse.

"5th. As Mr. SMYTH is an expert photographer, he should be provided with an apparatus for obtaining photographic impressions of everything worthy of record, *inter alia*, the great Dragon Tree of Orotava (supposed to be the oldest tree in the world), from several points of view. Of course accurate girth measurements of this most wonderful object, at several levels from the ground (defined by marks left on the trunk), will not be neglected.

"6th. The polarization of the sky light, at the summit of the mountain, should be carefully examined, and the point of maximum polarization, with respect to the sun's

place, determined with the greatest attainable precision *for homogeneous light* of some definite refrangibility, as well as the ratio of polarized to unpolarized light.

"7th. A very interesting series of astronomical observations on refraction might be made, should time be allowed, if a good altitude and azimuth instrument could be furnished, and erected at or near the summit; consisting in determining the form of the apparent diurnal orbit of a star passing through the zenith, and α Andromedæ would be an excellent star for this purpose. It passes *almost exactly* through the zenith of the Peak; and supposing the observer to be there in August, it rises about three hours after sunset, and reaches the zenith about as much before sunrise, affording the most favourable conditions for regularity in the disposal of the atmospheric strata.

"8th. The observer's attention should be directed to any instance of *lateral* refraction, like that remarkable case described by HUMBOLDT as having occurred to him at Orotava.

"9th. The temperature of the sea-water, taken up from about 10 feet below the surface, should be determined daily, or several times in the day and night, on and near the tropic, if possible, to the hundredth of a degree.

"10th. It would be most desirable also to procure thermographic representations of the solar spectrum (as described in my paper in the Philosophical Transactions, 1842), and to examine the 'fixed lines' of the luminous spectrum, with a view to ascertaining whether they, or any of them, originated in absorption of the earth's atmosphere.

"I have the honour to be, Sir,
"Your very obedient Servant,
(Signed) "J. F. W. HERSCHEL."

III.—*Letter from Lieut.-Col.* JAMES, *R.E., to the Secretary of the Admiralty, dated Ordnance Map Office, Southampton, 5th May*, 1856.

"SIR,—1st. I beg to acknowledge the receipt of your letter of the 2nd inst., informing me that the Lords Commissioners of the Admiralty have sanctioned a scientific expedition to Teneriffe, under Professor PIAZZI SMYTH, and requesting me to offer any suggestions which may occur to me for the better carrying out of the object in view.

"2nd. It is peculiarly gratifying to me to learn that so immediately after the conclusion of peace, an enlightened Government has turned its attention to the promotion of science.

"3rd. The special object which the scientific world have in view, when they urge the Government to avail themselves of Professor SMYTH's voluntary offer of his services, is to obtain that closer (so to speak) and more perfect view of the heavenly bodies which is to be obtained at a great elevation and in a purer atmosphere than can possibly be obtained in this or perhaps any other part of the world.

"4th. From Professor SMYTH's known powers as an accurate observer, and from the singular facility and felicity with which he is able to represent and describe what he

sees, I anticipate that this special object will be successfully accomplished by him.

"5th. He will of course be furnished with one or two of the best portable telescopes which England can furnish, for which he will require one or two tents, especially made for the purpose, and which, with the sanction of the Treasury, I could have made here; in addition to which he will require an order for the issue of two marquees or bell-tents from the Tower, or some other military depôt, for himself and attendants, with a supply of stretchers, bedding, and cooking utensils; and as the steamers for Teneriffe start from this port, I shall be happy to receive them here, and see that everything is properly provided to enable the Professor to carry on his duties effectually.

"6th. In the foregoing observations I have confined myself to the special object which Professor Smyth had in view, and the appliances to effect it; but Teneriffe, from its great altitude, its symmetrical form, its position on the confines of the tropics and the trade-winds, is the most remarkable landmark on the face of the earth, and its meridian was long ago proposed to be the first meridian for all nations; and I should truly rejoice if the Government, in addition to sanctioning the necessary expenditure for observations on the surface of the heavenly bodies, would also sanction the necessary expenditure for observations by which their mean density might be determined with more precision than it is possible it could be on any other spot on the earth.

"7th. My attention has been specially directed to this point of late; the primary triangulation of the United Kingdom has just been brought to a close, and from it we have deduced the form and dimensions of the earth. In the autumn of last year I had observations made at Arthur's Seat near Edinburgh, for the purpose of determining the mean density of the earth; the results of these observations and computations will be read at the Royal Society on Thursday next, the 8th inst. The determination of these points is of the very highest importance in physics; the size and density of the earth are our only units of measure by which we can calculate the distance, size, and density of the heavenly bodies; and I could not but feel how much more valuable and trustworthy would the observations which were made at Arthur's Seat have been if they had been made on the flanks of the Peak of Teneriffe.

"8th. The Peak of Teneriffe is in round numbers 5000 times greater in its mass than Arthur's Seat, and its attraction, as affecting the plumb-line, cannot be much less than twenty times greater. The Peak is also, from its form and mineral structure, peculiarly well-adapted for such observations, and I feel that if Her Majesty's Government would sanction the necessary expenditure, there is no scientific research which would be viewed with greater interest by the whole world.

"9th. The command of so large a body of trained observers and surveyors as we have on the Ordnance Survey, fortunately enables us to undertake this investigation at no great expense, and with little interruption to the progress of the National Survey. I do not anticipate that the party need be absent from England more than four months, and it would consist of not more than eight Sappers from the Survey, and about twenty

young Sappers from Chatham; but we should require the attendance of a convenient-sized steamer, under an experienced officer in hydrographical surveying, not only to take out and bring back the party, and to enable us to visit and supply the parties round the Peak from the different points on the shore; but also for the purpose of taking accurate soundings, by which the configuration of the ground under water might be known.

"10th. The observations which I have here contemplated, in addition to those undertaken by Professor SMYTH, are,—

"(1). To ascertain the difference between the geodetical and astronomical amplitude of an arc of meridian, drawn through the Peak, from which to deduce the mean density of the earth.

"(2). The difference in the time of vibration between a pendulum on the summit and near the level of the sea, from which we can also deduce the mean density of the earth.

"(3). The geological structure of the Peak, and its mean specific gravity.

"(4). Meteorological observations at different altitudes in the trade-winds towards the equator, and in the upper current from it.

"11th. The Government has now a large number of steamers fitted out and suited for this purpose; there can therefore be no more convenient, as there can be no more appropriate, time than this, at the close of a great war, for undertaking a scientific expedition, which will be hailed with satisfaction by the whole civilized world, and emphatically mark the return of peace.

"I have the honour to be, &c.,

(Signed) "HENRY JAMES,

Lieut.-Col. Royal Engineers."

Report of the Committee appointed by the Council of the Royal Astronomical Society, to consider the recommendation for the Teneriffe Expedition.

"The Committee recommend the following subjects as particularly desirable to be attended to, so far as they do not interfere with the more special objects proposed by Professor SMYTH:—

"1. The practicability of rendering visible the red prominences on the margin of the sun.

"2. Observations on the solar disk generally, including faculæ near the border, and the alleged diminution of light towards the edge.

"3. Observations of the disks of the planets, and especially of Venus, with respect to irradiation, and also to her atmosphere, and possible satellite and spots, with the view of determining her rotation.

"4. Observations on double stars and nebulæ, with the view of testing the effects of a purer atmosphere, with especial attention to Antares and his companion at the approaching occultations.

"5. Solar refraction, in reference to Professor THOMSON'S theory.

"6. Determination of the constant of atmospherical refraction, by observation of zenith distance of circumpolar stars.

"7. Observations on the zodiacal light, with reference to recent theories.

"8. Observations to verify HUMBOLDT'S remarks on the *lateral* oscillation of stars near the horizon, and on scintillations generally.

"9. Attempts to determine the polarization of the light of asteroids and faint planets.

"10. Observation of the fixed lines in the solar spectrum.

"11. The usual meteorological observations, especially of the humidity directly by DANIELL'S hygrometer.

"12. Surface-radiation from various substances, and the intensity of solar radiation.

"13. The determination of the height of the Peak by barometer, and the lowest snow-line on different sides of the mountain.

"14. The distribution and limit of vegetation on the mountain.

"In proposing this list of subjects, the Committee do not wish to be understood as pressing *all* of them as of equal importance, but simply as suggestions subordinate to the main objects of the expedition, though they think the more material are Nos. 1, 5, 7, 10 and 12. With respect to No. 6, they also propose it only in case the Professor is prepared to undertake such a series of observations as would be necessary.

(Signed) "BADEN POWELL,
"ROBERT MAIN,
"R. C. CARRINGTON."

"24*th May*, 1856."

"Royal Society, 3rd June, 1856.

"The President and Council of the Royal Society have learnt with satisfaction that it is the intention of Government to send an expedition to the island of Teneriffe, for the purpose of observing astronomical phenomena in a locality peculiarly favourable for that class of observations which are most obstructed by the action of the atmosphere. The nature of these observations, and the best mode of carrying them out, have already been maturely considered by Professor SMYTH, with the assistance of the Astronomer Royal, so that it is quite unnecessary for the Royal Society to offer any suggestions on that head.

"But while the astronomical observations for which the expedition was undertaken must be the grand object of the observer's attention, there are some other subjects for the investigation of which the expedition offers a peculiarly favourable opportunity. In consequence of the short time during which Professor SMYTH is likely to remain on the Peak, and the necessary devotion of his principal attention to astronomy, it would be useless to suggest any collateral investigations except such as could be carried out in a short time and with a moderate expenditure of labour; nor do the President and Council suppose that it will be found practicable to attend to all the suggestions they may make, especially as the expedition is so shortly to sail. The following suggestions are offered :—

"1. The determination of heights by barometric observations is liable to be influenced, to an extent at present unknown, by the state of motion of the air, and other similar disturbing causes. Much useful information on this point might be obtained by taking out three or four barometers, to be planted, one at the station chosen near the top of the mountain, and the others in different directions round the base, especially one towards the windward and another toward the lee side of the mountain, with reference to the prevailing winds. The barometers should be observed at the same hour several times during the day, and the temperature of the air, and likewise that of the mercury, unless the two may be assumed to be the same, as well as the dew-point, should be registered, the direction of the wind noted, and its velocity estimated, at each observation. It is supposed that persons might be found, who, either from an interest in the subject or for a small pecuniary consideration, would undertake the registration of the barometers placed at the base of the mountain. One or more barometers might be placed at different altitudes, should habitations and suitable observers be found. It is to be hoped that time may be allowed for an independent determination of the difference of altitude of the stations by triangulation or levelling.

"2. The temperature and hygrometric state of the air might be determined at intervals in ascending or descending the mountain, a portable barometer being read at the same time, so as to give the altitude, and the transitions from one aërial current to another, whenever they occurred, being noted. These results would be especially interesting for comparison with those obtained in the recent balloon ascents of Mr. Welsh, undertaken under the direction of the British Association, and the more ancient observations of the same kind.

"3. Interesting information might be obtained relating to the absorption of the solar rays by the atmosphere, considered with reference to their total thermic effect, by making observations at different altitudes with Sir John Herschel's actinometer.

"4. As some of the fixed lines of the spectrum appear to owe their existence to the absorption of light by the earth's atmosphere, it would be interesting to compare the lines seen at the mountain top station when the sun is low, with those seen about the middle of the day, and those again with the lines seen at a small elevation above the level of the sea; and it would add much to the interest of the investigation if photographic impressions of the lines could be taken.

"5. Certain observations seem to show that the atmosphere is to a certain extent opake with regard to the more refrangible of the solar rays, so that it seems likely that the spectrum would be found to be of greater extent, on the more refrangible side, on the top of a high mountain than below. This point could easily be decided by forming a pure spectrum with a quartz apparatus, and receiving it on a piece of glass coloured by uranium, or on some other substance possessing a similar property.

"6. Observations might be made on the polarization of the light of the clear sky as seen from the top of a mountain, especially with reference to the determination of the neutral point or points, if any exist.

"Many subjects of investigation relating to astronomy, physics, or meteorology, will probably suggest themselves to the observer when on the Peak, the selection and elaboration of which are best left to his own judgment. There are also various points of interest relating to the geology and geography of this region, which Professor SMYTH may possibly find time to attend to.

(Signed) "WM. SHARPEY,
Secretary."

(3.) *Execution of the Work.*

Having embarked at Southampton on board Mr. STEPHENSON'S yacht 'Titania,' with all the instruments and baggage, we crossed over to Cowes for stores, and setting sail from thence on the 24th of June, reached Santa Cruz in Teneriffe on the morning of July the 8th. On July the 14th we ascended the mountain with the greater part of the instruments, and occupied a station (Guajara) on the circle of the "great crater," at the height of 8903 feet, from that evening until August the 19th. On the 20th we ascended to a more elevated station (Alta Vista) on the sides of the Peak, or central cone, at a height of 10,702 feet; from thence visited the top of the mountain, 12,198 feet in height; and finally descended to the sea-level on the 19th of September. On September the 26th we re-embarked in the yacht, and returned to Southampton on the 14th of October; having, with an absence from home of 113 days, spent so large a proportion as 65 days at the heights mentioned above.

The chief numerical results are contained in ten MS. books, as thus:—

Vol. 1. Astronomical and Physical Journal.
Vol. 2. Mountain Meteorological Journal.
Vol. 3. Reduction of the above.
Vol. 4. Sea-level Meteorological Journal.
Vol. 5. Reduction of the above.
Vol. 6. Illustrations to the Astronomical Journal.
Vol. 7. Results and Conclusions,—Astronomical.
Vol. 8. Results and Conclusions,—Physical and Meteorological.
Vol. 9. Results and Conclusions,—Geological, Botanical, &c.
Vol. 10. Photographs.

From the manner in which the observations are exhibited in the above books, they will be found, I trust, to explain themselves. In many cases they must be studied originally and in the full, to enable all their meaning and significance to be appreciated. In others, I may be able to save investigators some trouble, by collecting together all the measures of special phenomena, and indicating the results and conclusions to which they lead, as in the following pages.

No inconsiderable part of the thermometric and other meteorological observations on the mountain were made by the second mate of the yacht, WILLIAM CORKE, who accompanied me there, together with the carpenter, WILLIAM NEALE, whose services were of

extraordinary importance in repairing damages to instruments caused by the dry atmosphere above the clouds, and in adapting materials and means to the novel circumstances in which they were placed.

For the sea-level observations taken during the same period, all acknowledgements are due to the captain of the yacht (Loving Corke), who made the whole of the said observations himself, and with strict attention to the principles laid down to him.

Very lately I have had the pleasure of receiving from Teneriffe a large mass of tide observations, taken under the immediate superintendence of Don Francisco Aguilar, a Spanish civil engineer, engaged on the repair of the Mole, and inspired with the most laudable enthusiasm for the promotion of science. Finding that these observations have been made exactly in accordance with the desired instructions, and having personally examined the tide-gauge, erected for the purpose under the care of the Don and Mr. L. Hamilton, I have great satisfaction in including the Spanish contribution in the present report.

CHAPTER II.

DEDUCED IMPROVEMENT OF ASTRONOMICAL VISION WITH HEIGHT.

(1.) *Vision and Definition.*

This important question was quickly and satisfactorily settled on Guajara; for by frequent trials during several years in Edinburgh, I had ascertained the range of vision with the Sheepshanks telescope to extend to the 10th magnitude; I had never, for instance, been able to see the companion of α Lyræ (11th magnitude), even when selecting the most favourable nights, and with the star only 5 degrees from the zenith; while with the same telescope and the same eye on Guajara, at 8903 feet of height, and with α Lyræ 25 degrees from the zenith, the companion was always and easily visible, more so than the companion of Polaris (9th mag.) used to be in Edinburgh. Smaller stars still were also observed, as C of 5 Aquilæ (14th mag.), D of 13 Lyræ (12th mag.), B of δ Aquilæ (12th mag.), B of 128 Anseris (13th mag.), B and C of β Equulei (13th and 14th mags.). Stars of the 15th and 16th magnitudes, looked for, were not seen, as was the case also with one of the 13th magnitude.

An extension of telescopic vision through four magnitudes is thus made out, and would be an inestimable addition to our larger classes of telescopes; for much of the advance seemed to be owing to improved definition, as well as to the transparency of the air.

This fine definition was shown in the perfection of the images of the stars, which, five nights out of six, exhibited clear little disks surrounded by regular rings, when viewed under a magnifying power of 150, and contrasted most favourably with the amorphous figures that the same telescope had always given in Edinburgh. When there, indeed, I had been at a loss to understand how accurate measure could be applied to the double stars; but on Guajara the appearance of every double star seemed, by its finish and exactness, to provoke one to apply a wire micrometer to it.

The usual test of definition, the separation of close double stars, especially when there is much difference in their size, was tried at the Alta Vista station with the Pattinson telescope. I cannot, unfortunately, state comparative results with this instrument; for though I visited its hospitable owner in England on three different occasions, at intervals of several months, yet the sky was invariably clouded. We have therefore only to look to the aperture of the object-glass, 7·25 inches, and compare its performances on the mountain with those of instruments of the same size elsewhere.

ϵ Arietis, λ Cygni, 52 Arietis, all double stars, and with the distance of their components given in the "Cycle" at under 1″, were completely separated. B and C of γ Andromedæ, with a distance of 0″·5, night after night, and on one occasion at so large an hour-angle as 4^h 30^m, were seen divided, but not exactly separated; for although there certainly was a dark line between them, yet the disks were mutually compressed on that side to a small extent. A diagonal eyepiece with a transparent reflector did separate the two disks completely, by making them smaller; but the definition was so much injured, that this testimony to the duplicity of the star and the excellence of the telescope, was not deemed more satisfactory than that afforded by the direct eyepiece with its larger and brighter stellar images.

The excellence of definition at Alta Vista seemed to extend over the whole sky, and was still most satisfactory when, toward morning, I examined Saturn heliacally rising in the east. The fine division of its outer ring, and the transparency of the dark ring, were abundantly manifest; but the general perfection of finish as it were of the borders of both ball and ring, struck me as the most noticeable point; for even with a power of 500, I could not fancy anything more clear at its edges than they were.

These observations were repeated on Saturn during several mornings, and are all the more noteworthy, since that is about the time when telescopic definition in most observatories becomes exceedingly bad. On the mountain the sun was seldom well defined, and his excessive radiation seemed to disturb the air, and in a manner that often lasted in the western regions long after he had set; but night usually succeeded in quieting the commotion.

(2.) *Agents in producing good definition.*

Thus far the facts of observation have been stated; and the main explanation of them is evidently the other fact, that when looking at the stars on the mountain, we were not looking through those grosser and denser strata of the lower regions of the atmosphere through which ordinary observers must look. On the mountain we found another circumstance operating, whose existence is not generally suspected: this is the prevalence of excessive drought. Had there been any actual formation of dew, there would have been difficulty in keeping the glasses free; and with the smallest portion forming on them, adieu to all delicacy of vision. But in a region where the average depression of the dew-point was, as we found it, the unheard of quantity of 40°, and where it was not unfrequently above 50°, the formation of dew was physically impossible.

Hence some of our best observing nights were on occasions that in a moister atmo-

sphere would have been impracticable; for the calmness of the atmosphere and the radiation of the sky, inasmuch as depended on them, tended powerfully to the formation of dew. Thus at Guajara, on the 4th of August, when an unsurpassable definition seemed to reign all night long, and there was no wind and no cloud; and in so far there ought to have been dew on the object-glass, whose temperature must have been brought down far below that of the surrounding air,—for the radiation of the sky amounted to 17° (that is, the temperature under cover was 50°, and the temperature of a black-bulb thermometer exposed to the sky was 33° at 2 A.M.),—yet the temperature of the dew-point being at the same moment only 19°, no clouding of the object-glass took place.

Comparing our observations on the mountain with those of Mr. Welsh in his balloon ascents, and the more ancient observations from De Luc and Saussure downward, this excessive dryness above the clouds may be considered a universal phenomenon; though the absolute height at which it most signally prevails, depends on season and other effects. Thus in Teneriffe, throughout the summer, the dry atmosphere may be secured at so small an elevation as 5000 feet; but in autumn and winter (see the Mountain Meteorological Journal for September the 14th), we should have to rise occasionally so high as 12,000 feet, in order to reach it.

(3.) *Daylight Observations of Stars.*

Sundry notices of stars picked up during the day with the Sheepshanks telescope on Guajara are scattered through the Astronomical Journal, but its performances in this way were not strikingly better than in Edinburgh. Some allowance must undoubtedly be made for the very untoward circumstance of the telescope on the mountain being exposed in the open air and bright sunlight, while in Scotland it had been employed in a dark room, with only a small aperture for vision in the roof. Over and above this cause, much of the want of greater success in the day observations must be attributed to illumination of the atmosphere by the sun. True, that the atmosphere becomes more transparent as we ascend, but the brightness of the sun increases at the same time, and the multitudinous reflexions of its light from motes in the air increase more intensely still.

Hence, as long as the sun is above the horizon, daylight on the mountain is almost as fatal to stars as on the plains. The blue of the Alpine sky, which has been spoken of by travellers as something so deep as to verge on black, we did not find even on the culminating point of the Peak, at 12,200 feet of altitude, to be anything extraordinary. When observing the sky in immediate proximity to the sun, as for the eclipse red prominences, the field of view was so intensely bright, that a very dark glass was necessary to protect the eye; and even when using the faint reflexion from the transparent mirror of a sun-eyepiece of the Pattinson equatorial, considerable practice was necessary before one's eye could withstand the glare.

This rendered a search for stars very near the sun quite hopeless; and even when

looking for them at greater distances, as 10 and 15 degrees, there was ever more or less of a luminous pattern on the object-glass, caused by the all-powerful sunlight striking on microscopic imperfections on the surface.

With all this, however, I observed by day many more stars than I had ever done in Edinburgh; but the more marked result was, the far greater brightness of the bright stars. The preponderance of Sirius, for instance, above all other stars, was never so powerfully manifested to me before; and from his excessive and staring visibility, one came down at once through an immense number of measurable gradations to Arcturus, the next brightest star visible, and perhaps arrived at total invisibility with a star of the third magnitude.

(4.) *Naked-eye Observations.*

The stars shone brilliantly, as seen from Guajara, and caused the dome of the skies to appear resplendent with glory; the Milky Way was a magnificent feature in its scenery, and the zodiacal light towards morning was still more remarkable. Jupiter also was surpassingly brilliant when high in the heavens after midnight; but I could never see his satellites with the naked eye, not even when eclipsing the planet behind a distant lava ridge. When treating the bright part of the moon in a similar manner, the illumination of the dark part appeared conspicuously, though the first quarter was past. With the new as well as the old moon, when forming a crescent, the brightness of the surface was such, as, acting by irradiation on the eye, to give an appearance of unnatural bluntness to the horns. She gave one, moreover, at once and visibly, the real idea of being closer than the stars; while the "shooting-stars," of which by the way we did not see any displays remarkable either for number or brightness, appeared absurdly close; and, having a reddish light, looked even like sparks of fire flying through the air.

We were much struck on the mountain by the quiet and steady planetary light of the stars, and were inclined at first to say that they did not twinkle; but we soon found that they did so, though to a much smaller extent than in the plaisn below. Having lately become acquainted with Professor Dufour's method of applying the principles of numerical observation to the scintillation of stars, and the rich results that he has already deduced from very simple beginnings, I regret that I did not attempt something of the same sort on the Peak; though perhaps nothing short of his own skill and experience would be required to do justice to the natural capabilities of the place.

(5.) *Qualities of the Atmosphere.*

The astronomical qualities of the atmosphere may be divided into two species,—the immediate or particular, as wind, fog, &c.; and the general, as distant clouds, haze, and other aërial impurities.

Wind is usually a terrible drawback on the availability of mountains for observatory purposes, and the tops of the lower hills in Teneriffe, at about the level of the trade-wind cloud, are swept by it with terrific force; but above that height, the wind, still preserving the same N.E. direction, continually decreases in strength, until it reaches a

neutral stratum below the S.W. wind, which appears there to be always the direction of the upper current in the atmosphere, in the summer at least, for which season alone my descriptions are intended to apply.

The height of this neutral region would seem to vary much; sometimes it was below, but much more generally above 9000 feet. Hence we had more N.E. wind than S.W. at Guajara; but being in the neighbourhood of the neutral stratum, neither wind was felt in great force, except on one occasion, when for several hours in the morning the N.E. wind blew with a velocity of from twenty to thirty miles per hour.

This circumstance in itself confirmed the conclusion already drawn from the number of days that each wind was felt, viz. that we were much nearer the N.E. than the S.W. current. And finding that in proportion as the former (N.E.) predominated, so did faint dusty impurities in the air, and bad definition, we proceeded to establish a second station at "Alta-Vista," at the height of 10,700 feet. Our earlier experiences on moving there confirmed the truth of the idea, for there was on the whole less wind than at Guajara, and it was more evenly balanced between the two directions. Our later experiences at that station included the setting in of autumn, which broke in upon all the regularity of the summer weather, and need not here be alluded to further, as our experiment was only intended to utilize the summer season.

With wind then we were visited but moderately, and we were equally fortunate with regard to fog or mountain clouds; for though they existed below and appeared daily, dense, closely packed together, and rolling upon each other, they showed no tendency to rise higher than 4500 feet. With this depression of the mountain cloud, including cumulus, cumulostratus, and nimbus below us, we had but the thinner forms of cloud, cirrus, cirrocumulus, and some cirrostratus, ever at any time floating above us, or interfering with the view of the heavens. These only appeared about once in five days in any considerable quantity.

A more important quality of the atmosphere was caused by the dust-haze, which was ever more or less present, though sometimes in vastly greater quantities than at others, and was precisely that which injured, or rendered impossible, daylight observations of stars. Where this dust-haze came from or went to we could never tell; but, when present, we could easily distinguish its banks, or strata, as they stretched away and condensed in perspective towards the horizon. There were often several strata, one above the other, and mutually separated by very clear and sharply-defined spaces of atmosphere. When, as was sometimes the case, the summits of Grand Canary, or of Palma, rising high above the sea of clouds, pierced also these upper strata of dust-haze, we had, from Guajara, the curious phenomenon of zones of blue mountain alternately distinct and again indistinct almost to invisibility, and yet no cloud or other recognized impurity of the atmosphere intervened.

Being above much of this dust, though perhaps not the greater part of it, we were evidently better off than an observer at the level of the sea, when pointing to a zenith object; but for a horizontal one we were worse off, from often being *in*, and then look-

ing *through* the whole plane of the stratum, and so experiencing the maximum of its light-stopping effect.

Hence the occasional deterioration of sunrise and sunset were infinitely greater than anything that occurred at noon; and on some days, when the sky was perfectly free from cloud, and the sun had been distressingly hot and bright when high in the sky, yet it had almost become invisible before it set. It was seen, though made out with difficulty on such occasions, through a darkling, yet luminous haze of dull lemon-yellow colour; but what it set behind, or when exactly it did set, there was no ascertaining.

The next evening perhaps the atmospheric dust had removed, and the change in the sunset was magical. The orb radiated hot and shone bright up to the moment of going down, sometimes behind Palma, showing hills of rich dark purple; sometimes behind the rollers of the cloud sea, clearly visible to the extreme verge of the horizon. Then, too, in place of the uniform yellow colour of the dusty sunset, the most gorgeous scarlets, yellows, and blues took its place.

To eliminate this dusty medium would be of the utmost importance to the further improvement of astronomical observation, and may be considered the greatest and most subtile difficulty which the observer has to deal with; and it is probably general over the world, as on the South African mountains, at heights of 5600 feet, the phenomenon was almost as notable as on Guajara. From Dr. Mason's observations of solar radiation in Madeira, and from the relations given to me by inhabitants of Teneriffe as to the periods of the year when the Peak is seen most clearly, I am disposed to think that there is least of this dust in the atmosphere in the latter end of the winter and the earlier part of the spring. The latter, if not the former also, would probably be a practicable time for mountain observation; for one of the most remarkable results of our meteorological inquiries, is the indication of the seasons being nearly two or three months earlier at a height of 10,000 feet than at the sea level; so that the difference of temperature in the spring, between the two zones, is by no means so great as in autumn.

CHAPTER III.

ASTRONOMICAL OBSERVATIONS PROCURED.

(1.) *Double Stars.*

The Astronomical Journal contains many notices of double stars, but as they were merely for the purpose of testing the performance of the instruments, the nature of the objects was always assumed to be known (the "Cycle" being adopted as authority), and our aim was rather to take an eye recognition of as many objects as possible, than to apply rigorous measure to a few. Several cases of change in magnitude, distance, and position were however encountered, and are given; many stars were also observed for colour, to compare with observations below. These will be found duly entered in the

Journal; and the only remark that need be made here, is, in connexion with the astonishing visibility of the companion of Antares, which escaped Struve, with an instrument wherewith he discovered the duplicity of B and C Andromedæ, and so many other difficult tests. When we bear in mind the great altitude of these latter stars in Russia, and the very low altitude of Antares there, the case may be taken as a strong illustration of the importance of eliminating atmosphere from observation in every possible way; not only by climbing up a mountain, but by each observatory confining itself to the objects in the neighbourhood of its own zenith.

(2.) *Moon and Planets.*

At Guajara, with the Sheepshanks telescope, there were many tempting opportunities of delineating parts of the moon's surface; but the small power of the telescope prevented such work being as good disposal of my time, as many other observations that equally claimed attention. Moreover there was so remarkable a tendency of bright points of the lunar craters to form stellar disks and rings, that I was additionally induced to defer anything in this line, until the Pattinson equatorial with the transparent glass reflector-eyepiece should be erected.

This instrument was established at the Alta Vista in September, but the last quarter, which was to have been the lunar observing period, was interfered with by the premature setting in of autumn. In the first quarter of that month we had several opportunities, but not many or good ones, as the moon was then very low in southern declination, and the lava ridges rose high to the west of us.

Those few views, however, with magnifying powers from 160 to 560, made a most vivid impression on the minds of all at the station. There have been doubts expressed by some geologists, as to whether the circular cavities in the moon are craters; had they enjoyed these opportunities at the Alta Vista, they would have renounced such doubts, so many and so striking were the analogies between the craters of Teneriffe and those we saw in the moon. Among the most characteristic perhaps of the resemblances, is the greater steepness of the inner over the outer wall of every cavity or ring-shaped mountain; again, the precipitous ledges, and often the conchoidal bays and recesses of the inner wall; and the generally level floors of the cavities, with here and there a peak raised upon, or a little cup-shaped cavity established in them.

But the telescope showed over and above those well-known features, such an infinity of detail, that though I tried once or twice (see the view of Autolycus in Plate XXXIV.), I found it quite impossible to make a proper drawing of any notable part, in the contracted space of time between darkness and the moon going behind the lava ridge. Half a night would have been short time enough. In this department there is indeed an immensity to accomplish; the clear air of the Peak would be most favourable; and the opportunity that the astronomer would have, probably for the first time in his life, for ascertaining the distinctive forms of terrestrial craters from eight miles in diameter to 300 feet, would enable him to appreciate better the minute revelations of

the telescope. Of all the subjects connected with the lunar surface, to which attention may be directed, none perhaps is so important as the detection of what may be called the dynamic wrinkles of lava streams. These at once distinguish the lava stream from the avalanche of stones; and, as would appear on the Peak, lead to much insight regarding the temperature, fluidity, and order of the emitted streams. From the small size, however, of such wrinkles at Teneriffe, the successful observation of them in the moon would demand the best of existing telescopes, the highest magnifying power, and a rarefied mountain atmosphere.

Jupiter near the zenith was a sight very different from anything that European astronomers have had for many years past; I attacked it therefore with zeal as to optical features. At Guajara, with the Sheepshanks telescope, it was remarkably well defined, the belts clear, and the shadow of a satellite occasionlly crossing the disk was strong; but with the exception of a scolloped or festooned appearance in one of the belts, nothing new was seen. The interpretation of this peculiarity was left for the Pattinson equatorial at Alta Vista. There, with a power of 360, the bright spaces between the belts resolved themselves into masses of cumuli, cumuloni, and cumulostrati,—the drift doubtless of the Jovian trade-wind,—in their forms and gatherings so precisely like those which the terrestrial trade was accumulating round Teneriffe below our feet, that I could not avoid applying the same name to similar forms.

Three drawings of these appearances—they might almost be called revelations—in Jupiter are inserted in Plates XXXIII. and XXXIV. The originals were begun and finished at the end of the telescope, and each was made on a different evening, and without any reference to the previous views; so that the one may be used against the other, in determining the probable error in the representation of any particular feature of interest. Due allowance must of course be made for the change of the mean meridian each night; indeed during the time occupied in the drawing, the shifting of the whole of the forms, from rotation of the planet, was most perceptible without applying measurement; but over and above this, there were minute yet indubitable changes of shape in the cloudy appearances during two hours.

Of Saturn two drawings were made, but beyond satisfactorily showing the fine division of the outer ring, there was little to be done on account of the low position of the planet. One of the drawings, however, may be referred to (vol. 6, page 28) for the appearance presented in the telescope; the second was a mere sketch taken the following night to test the characteristics of the first.

A single drawing should not be looked on, by itself, as of importance in the present state of astronomy; for how can others than the artist prove the reality in nature of anything they may find in that one document, when this alone is before them? A bad designer will often unconsciously give an erroneous figure; and though intending to show perhaps the blurred outline he actually saw, may yet, by using a pen in place of a brush, represent the erroneous appearance as having all-perfect definition, and cause the juxtaposition of full white with deep black: and if he has put in these things and a

few others also by slips or bad drawing, we must take the whole as he has given it implicitly, or reject it entirely.

If astronomical drawing is to take a similar trustworthy and trusted place to numerical observation, in its own branch of subjects, we must in the first place with every man's work, eliminate errors in drawing and imperfections of the means and medium employed. How easily much of this may often be accomplished by *two* drawings, may be well seen in some of the photographs in the book of illustrations; for having been taken with stereoscopic intentions, they are all double. Hence, is there some doubtful mark in one? we have only to look to the other; and if the mark was in the scene itself in nature, it will likewise appear in the second view as well; but not so if it were merely a fault or imperfection in the surface of the plate.

After this first step has been accomplished, comes the more difficult affair of eliminating the personal and instrumental equation, from which source of error no object in the heavens has suffered so much as our present subject, Saturn. Thus the elongation of Saturn's rings in old drawings, not confirmed by micrometrical observation, may be mainly, if not entirely, attributable to the earlier observers—in their desire to intensify their discovery, and to prove that they had a clear perception of the sky intervening between the inner border of the ring and the ball—having pulled out the ends of the ring much further than they were justified; just as a sketcher invariably increases the steepness of all his mountain slopes. Again, up to even the last few years, the published drawings of Saturn, with a few bright exceptions, as the HERSCHELS', have exhibited such erroneous ellipses—that if the shape and dimensions of his rings and their divisions were to be computed on such testimony—they would be found to be endued with more anomalous deviations from their nearly circular form, than any one has ever ventured to attribute to them, and which the artists themselves had never intended.

To improve this state of things, Mr. DE LA RUE has lately not only given us such admirable drawings, as stamp him as the artist *par excellence* of Saturn, but he has, by his extensively distributed diagrams, produced a sudden and general improvement in all the current delineations of the planet.

My drawing, I find, approximates pretty closely to his, but in some of the smaller features inclines more to Captain JACOB'S view, as thus,—1st, the principal division is not perfectly black, but of the tint of the dark ring; 2nd, the fine division is not accompanied by a bright band; 3rd, the dark parts of the ball do not take accurately defined zones; and 4th, the shadow of the ball on the ring is remarkably sharply defined.

(3.) *Eclipse red prominences.*

Under the date of September the 9th, in vol. i., or the Astronomical Journal, will be found particulars of what may be an observation of one of the eclipse red prominences; but as the view of it was uncertain in the extreme, and all the other attempts that were made were entirely unsuccessful, I think it better to allow that this department of our work was a failure,—a failure not from any deficiency of the instruments, though these

might be further perfected, but from the qualities of the atmosphere, and chiefly from the dust-haze which was found existing in dense strata far above the clouds of the north-east trade-wind. The most likely method therefore to follow out on a future occasion would be, to try the experiment earlier in the season, when there is less of the haze existing; or to try some mountain higher still than Teneriffe.

(4.) *Solar Photography and Polarization.*

All our observations of the sun laboured under the inconvenience of being performed in the open air, and freely exposed to the direct solar rays: to guard against these the observer's head and the eyepiece were enveloped in a black bag. When this was accomplished, then came the greater difficulty of the excessive heating power of the sun, connected with its powerful radiation on a mountain. The eyepieces became so hot that they could not be touched, and the black bag was continually getting burnt, and with its smoke, irritating the observer's eye.

Somewhat depending on these untoward accompaniments, which might be much relieved on a future occasion, the definition of the sun was invariably worse than that of every other object in the sky. The year 1856 was, however, so near the minimum of solar spot-producing disturbance, that little of importance ever appeared on the disk. The only thing that I would particularize, is the "silk marking" observed on September 13th.

This was a feature almost defying any attempts to delineate by hand and eye, but should yield one would think to photography. Accordingly, with the assistance of the yacht carpenter, I improvised a photographic box to fasten on the end of the telescope, with a spring trigger to make an instantaneous opening and closing of the aperture. But success was small by reason of,—1st, the wooden box being often heated to smoking; 2nd, the shaking of the telescope; and 3rd, the rapid vibrations of the air causing bad definition.

Making the best of these circumstances, definition was still unprocurable, until by a series of experiments, the very unexpected result was found, that the chemical focus of the telescope was ·5 *inch longer* than the visual.

This circumstance seems to settle the question, that the rays which produce the photographic picture are by no means the luminous, and may, or may not, give us an idea of what we see with the eye. The black photographic effect of bright yellow is well known; and a similar diversity, and more in point with regard to the possibility of obtaining good solar photographs, was offered to me frequently in Teneriffe, chiefly in the lowlands, when taking photographic landscapes on collodion. It was this: a distant mountain range was seen with the most perfect definition of innumerable details about its flanks; the bushes, the cliffs, the dykes in these were distinct and even prominent to the eye; yet in the photographs, nothing but the faint, though well-defined outline of the mountain appeared against the sky; as if, in place of the sun shining on the mountain, it were on the other side and throwing the ridge into the shade. In a word, the

aërial effect was intensely exaggerated in the chemical medium, with every increase of distance and illumination. Of the latter, a good instance was shown in the facility with which at twilight a good photographic image of the moon was obtained; while by day, no matter how clear the moon shone out to the eye from the deep blue vault of heaven, no impression whatever could be procured*.

After meeting with these indubitable instances of the distinction between actinic and optic images, no photograph would be admitted as a decisive evidence on a certain point suggested for inquiry by the Astronomical Society, viz. the brightness of the centre as compared with the borders of the sun. But whether forming the sun's image on a screen, or looking at it direct, there was never the slightest doubt on my mind or my eye, as to the centre being very much brighter than the border. The centre was also whiter, the border being yellowish; and it was not at all from this cause that the borders were thought to radiate less light, for the difference was something far greater than variation of colour could explain. This experiment may be perhaps taken as conclusive: with the transparent-reflector eyepiece of the Pattinson equatorial, the field of view having a stop with a small perforation of about 3′ in diameter, I found that I could bear perfectly well to look at the border of the sun without any coloured glass; but I could not with impunity allow the stop to pass over the central regions of the solar orb, by reason of their surpassing brightness.

This result is confirmatory of the conclusions, I believe, of every observer but one, M. Arago; and he arrived at his unique view by means of a photometer, based on his polariscope; an instrument which I was also requested by the Astronomical Society to use on the mountain, and which I did not find very satisfactory.

The polariscope was arranged by its ingenious inventor to be applied to the eye end of a telescope, and doubling the image of any luminous object in the field, to colour them complementarily if they contained polarized light to a sensible degree; and this M. Arago is stated to have ascertained to be the case with planets and comets, but not with the fixed stars.

By Mr. Airy, the Rev. Baden Powell, and Mr. Cooke of York, I was furnished with various polarizing materials capable of being fitted up into such an arrangement; but on neither planets nor satellites, viewed with the naked eye, the finder, or the Pattinson equatorial, could I get the smallest indication of complementary colours. The planets in question were certainly not favourably disposed for the polarizing angle of their reflected sunlight; and before the moon arrived at that part of her orbit, the summer weather had broken up, and brought all our observations to an end.

(5.) *Rising and Setting of the Sun.*

Accurate observations of the time of rising and setting of the sun I had intended to make, under expectation of the phenomenon taking place behind the sea-horizon; but this line was never once visible during our whole stay on the mountain. In place of it,

* Further still, it was found that the photographic plate feels and renders at once all those additional rays, which in Stokes's spectrum the eye cannot perceive without the assistance of uranium glass.

was invariably the spurious horizon of the great stratum of N.E. clouds, at a varying height of perhaps 3000 to 5000 feet, and seen at Guajara under a zenith distance varying from 91° 5′ to 91° 11′.

The cloud attached to the mountain was not more than 2500 feet in altitude, and seldom stretched more than two or three miles away from it; so that what portion of sea was visible between its termination and the beginning of the sea-cloud, was, from our station, many degrees below the horizon, and quite useless for altitude purposes. In the case of the cloud floating over the sea, on the contrary, the extent from the mountain seemed illimitable; and from what we had seen for several days before reaching Teneriffe, we had every reason to believe, that generally round about that island, but chiefly towards its N., N.W., and N.E., a cloud stratum extends almost uninterruptedly for several hundred miles, always at the same height above the sea, and of the same generic character, or strikingly like the "cumulonus" of Admiral Fitzroy (see Plates XXX. and XXXII.).

The form was not improbably a consequence of the mechanical action of the trade-wind on the cloud-material; and though the rollers of mist, moving along always rapidly from N.E. to S.W., often had intervals between them when examined in *plan*, yet viewed as they were in extreme perspective on our visible horizon, no gaps were seen in that position; while their substance, condensed apparently by distance, made them form as opake an edge for the sun to rise behind, as a snowy mountain.

Although, then, the *absolute* time of sunrise so observed would not have been capable of geographic truth, its *duration* could be taken pretty well. All the more extraordinary therefore is the account by a celebrated traveller, that the one sunrise which he observed from a height of 11,000 feet on the Peak of Teneriffe, had the remarkable anomaly of occupying upwards of eight minutes.

Subsequent observation at the same spot cannot prove or disprove any exceptional mirage that may have occurred to a former observer; but it may indicate whether the locality is frequently liable to such extreme dislocations of refraction; and with this view, the rough naked-eye observations which I used to take at Guajara for meteorological purposes, and which are entered in vols. 1 and 2, may be examined, and will be found to show no anomaly of the sort on any occasion. A characteristic feature of mountain sunrise and sunset used certainly to be the very visible flattening of the solar orb; but this was a constant and normal phenomenon; and if it reached, by sextant measure, so large a quantity as 5′, that was but the proper refraction-effect, due to a zenith distance of over 91°.

(6.) *Duration of Twilight.*

Observations for the duration of twilight were found capable, on being actually tried, of more precision than might have been expected; two minutes + or — appearing to include all uncertainties as to the vanishing of the last trace of the sun's light in the west, or its appearance in the east, the zodiacal light alone excepted; but this quantity does not include certain natural causes of difference in one day from another, which will be found to vary much more.

At Guajara.

Twilight. Duration of, at sunrise.	h	m	Twilight. Duration of, at sunset.	h	m	s
July 22nd	1	2	July 17th	1	10	0
			July 21st	1	22	0
			July 23rd	1	26	0
			July 26th	1	22	30
			July 27th	1	19	0
			July 28th	1	16	0
			July 29th	1	22	0
July 31st	1	2	July 30th	1	21	0
August 2nd	1	13	August 1st	1	21	0
August 8th	1	17	August 2nd	1	18	0
			August 3rd	1	16	0
			August 17th	1	19	0
			August 18th	1	14	0
Mean, July 31st	1	8	Mean, July 30th	1	19	0

At Alta Vista.

Twilight. Duration of, at sunrise.	h	m	Twilight. Duration of, at sunset.
August 22nd	1	9	No sunset visible at this station.
September 8th	0	54	
Mean, August 31st	1	2	

The difference of duration observable here between the morning and evening twilight is remarkable, and may be partly owing to the difference of intensity of the zodiacal light, which in the evening was barely visible, but was in the morning so bright as to prevent the very first trace of dawn being perceptible.

The following are a few of the additional observations made respecting twilight at Guajara:—

On the morning of the 8th of August, the first symptom of colours was distinguishable nine minutes after the first appearance of light; while in the evening of July 17th, and on July 26th, the colours were on each occasion distinguishable to within five minutes of the cessation of light.

Further, on August 17th P.M., eighteen minutes before the end of twilight, its altitude to the extreme blue was found to be 9°. And again, on August 18th P.M., at twenty-one minutes before the cessation of twilight, the altitude of the extreme blue was found 9°, and to the extreme red 3°; while at eight minutes before the cessation, blue colours were alone visible, and reached 3° high.

At the latter periods of twilight, I had some confidence in attempting to measure the

altitude, but not at the earlier periods, when the light was far too diffuse and uncertain as to its boundaries.

(7.) *Zodiacal Light.*

At Guajara the zodiacal light was observable both east and west: at Alta Vista only in the east, on account of obstructions in the horizon westward. Notices of observations of this phenomenon will be found in the Astronomical Journal under dates of July 23, 26, 30, 31, and August 2, 7, 8, 12, 18, and September 2, 4, 5, 6, and 7. The objects proposed were, in the first place, to measure the place of the apex of the light; its length, breadth, and shape, and its angle with the horizon; and in the second place, to note any additional circumstances that could be made out bearing on recent theories.

In the western direction the appearance was very faint, but it was certainly real; and of three observations taken about half an hour after sunset on July 26 and 30, and August 18, we have the following mean quantities:—

For August 4th, at 17^h sidereal time	Length from horizon	50°
	Angles of inclination to horizon .	31
	Apex in Æ $13^h\ 26^m$ and D-10°	
	Length from sun	71
	Degree of brightness	$\frac{1}{4}$ of the Milky Way.

The greatest probable error of any of these observations, including all causes, natural as well as personal, may be $\pm 6^\circ$, and within such limits, and not to those of the last degree given, we may assume that the plane of the light is shown to be nearly coincident with the ecliptic.

In the eastern direction, the Guajara observations on July 31, August 2, 8, and 12, give, for the mean date of August 5, at $0^h\ 50^m$ sidereal time,—

Length from horizon	62°
Breadth of base	24
Angle with horizon	75
Apex in $3^h\ 48^m$ Æ and D$+21^\circ$	
Length from sun	76
Brightness	Milky Way $\times 2$

The angle of the ecliptic with the horizon at the same time being 70°.

At Alta Vista, observations obtained on September 2, 5, and 7, give for the mean date September 5 at 3^h sidereal time—

Length from horizon	63°
Breadth of base	27
Angle with horizon	79
Apex in Æ $5^h\ 20^m$ and D$+17^\circ$	
Length from sun	84
Brightness	Milky Way $\times 3$

The angle of the ecliptic with the horizon being 78°.

The brightness stated is that of the brightest part of the whole mass, which was usually some 20° to 30° below the apex. This point was rounded off, and the sides leading up to it were convex on the outside, in as far as one can speak certainly of such faint light; and tended much, by the regular and complete symmetrical form which they indicated, to distinguish it from the admixture of the Milky Way which crossed it. I could, however, at times fancy that there was a sort of wisp of the last degree of faintness stretching from the apex some 50° further across the sky; and on one or two occasions could almost persuade myself that it stretched all across the sky to the opposite horizon, but could never satisfy myself that it was not fancy.

Respecting alleged observations of the zodiacal light at midnight, the result of Guajara and Alta Vista is, that it was decidedly not visible there either east or west at that time (see August 7 and September 4); *i. e.* nothing certain, nothing that seemed either worth observing or even possible to observe; and assuredly nothing approaching the visibility of even the faintest part of the area, included in the ideal outline drawn each night on the sky, when it was seen E. or W., so as to include everything that could be at all acknowledged for zodiacal light. Westward it was not seen in the evening within three hours of midnight; but eastward, and on the high elevation of Alta Vista, something was just visible at about 1 A.M.; a difference explainable by the already stated numerical results, where the length from the sun in the eastern sky is given at 13° longer than in the western, and the brightness at twelve times greater. The midnight observations may also be considered conformable to the absolute solar lengths found at other times, viz. 71° and 84°.

If, then, at midnight nothing was seen, and at the best period of visibility afterwards, viz. from 3 to 4 A.M., the greatest measured solar length of any acknowledged portion of the zodiacal light was 84°, it follows that a glow occasionally seen in the western sky at that morning hour, could not be the other end of the zodiacal light; for that would imply a length in the end, previously found the shorter, of upwards of 170°. The glow in the west, then, during the morning exhibition of the zodiacal light in the east, is but a reflexion of the latter on the atmosphere, and was closely paralleled on several occasions by similar reflexions of lunar dawn.

On August 18th there was observed with the lunar dawn a circumstance that looked at first very much like a lunar zodiacal light. At $17^h\ 5^m$ the moon's twilight was visible as a low flat elliptical arch of faint light; at $17^h\ 12^m$ it had manifestly grown pyramidal or pointed above; at $17^h\ 15^m$ the point had extended itself into a cone, all of the faintest light, 30° high and some 12° broad; at $17^h\ 20^m$ the moon rose. The cone looked exceedingly like a lunar zodiacal light; but on measuring its angle with the horizon and finding it always 90°, while the angle of the ecliptic at that part of the sky was only 38°, the appearance was manifestly a mere local phenomenon of lunar dawn.

The change from the flat arch to the pointed cone is to be observed in the solar dawn as well; and with the latter, as seen from the mountain, accompanied by overpowering light and brilliant colours, is precisely the feature which used to make the measure-

ment of the "altitude" of twilight very difficult, when not far removed from the time of the sun's appearance.

Considering the lunar phenomenon again with the solar, the cone, if it had been the moon's zodiacal light, ought to have appeared *before* and not *after* the first formation of the twilight arch; and it ought to have been some hundreds of times fainter than when it so appeared, as the lunar representative of the intensely brilliant pink blush preceding the solar day; and yet, as such, it was not much more than barely visible. What then must be the almost inconceivable faintness of the lunar zodiacal light, if it exists in the manner explained on the terrestrial hypothesis, and how many grades must it be below invisibility to all ordinary human vision?

Another remark recent theories appear to require. Even when holding the heliocentric nature of the zodiacal light, some authors speak of it as a "*ring*," with a large interstitial space between it and the sun. The view from Alta Vista was as favourable as any observer ever had for detecting traces of a ring form, contradistinguished to the more generally received opinion of a lenticular mass gradually increasing in density towards the centre, where the sun himself is placed; and I looked particularly to the subject, as one bearing immediately on the recently published dynamic theory of the solar light and heat. The invariable result was, that not the smallest appearance of any traces of the ring form could be made out, but that every thing indicated a mass constantly increasing in density towards the sun. Down to the very horizon, for instance, the intensity of glow continually increased in the axis. This appearance, I may add, is also fully borne testimony to in the diagrams of the Rev. G. JONES.

These diagrams merit a more particular notice, not only because they are the largest printed contribution to our knowledge of the zodiacal light yet made, but because the author has deduced from them new conclusions as to the nature of the phenomenon. The particulars form the third volume of the 'United States Japan Expedition,' and it contains more than 700 quarto pages, of which one-half are engraved plates. Mr. JONES appears to be an honest, zealous, and most persevering observer. "Although," says he, "for six consecutive months, so sick as often to be unable to walk or stand without support, I still kept to my work; and the result, whatever it may be worth, has the merit of one uniform judgment trained by some experience, and stimulated, I know, by deep earnestness in the cause." His eye, too, must be powerful beyond the average of men, for he says, "I could, in clear nights, with the naked eye, easily make out stars of the 6th, and I sometimes thought of the 7th magnitude, through its (the zodiacal light's) densest parts."

In fact, while reading the introduction to the volume, I found everything to admire, until on page xi came this paragraph:—"There is no mention made in any books on the zodiacal light, of any differences in the light itself; but I very soon began to notice that there was a stronger light at the central part, or along the axis: while, beyond this, on either side, and also above, a dimmer kind of light extended itself, as if the matter giving us this light was more condensed at its central parts, and was thinned out beyond."

I cannot but wholly dissent from the opinion expressed above as to the publications

of others than Mr. JONES, and am perhaps not less qualified to do so, as I have long since, both in writing and in engraving, endeavoured to illustrate that same remarkable shading off of the light; and in doing so, gave it not as anything new, but as in the opinion of every astronomer, a leading feature in the appearance of the phenomenon, and a probable explanation of much discordance between different observers.

The shading off is, in fact, so very perfect over the whole extent, and the light, even at its maximum point of intensity, low down in its axis, so faint for human vision, that two different eyes, or two different degrees of transparency of the air on one and the same generally clear night, will entirely alter the apparent boundaries and size of the light. According, too, as the background of the sky may be lit up by moonlight or otherwise, from the smallest appreciable effect, to the maximum degree of the zodiacal light, so will this be seen to shorten from perhaps 60° to 5° or to 0°.

There can in fact hardly be anything more difficult to apply numerical measure to, than definite parts of the zodiacal light; it is like trying to determine the place of a comet from observations of the end of the tail only: and Sir JOHN HERSCHEL's admirable illustrations to his Cape volume, show some striking instances of the apparent alterations in size of HALLEY's comet, according to the amount of twilight illumination of the sky. When such are the natural difficulties of the case, many an observer would leave it altogether, and go to something to which measure can be applied rigidly, as the double stars; but we are not therefore all of us to neglect the zodiacal light. It is an existence in Nature, and if our usual methods of mensuration will not apply to it, we had better improve them.

One of the first elements that seems to be demanded, is some approach to a proof of the elimination of disturbing effects. It is not enough, for instance, for a man honestly to declare what he sees before him; he must understand the weight and effect of all attendant circumstances. When in South Africa, I found a whole season's observations rendered abortive by the presence of the planet Venus very near the zodiacal light, and rejected them accordingly: I cannot therefore understand Mr. JONES's observations with the moon in the same position, as being altogether unexceptionable. Generally, too, in my humble estimation, he hardly attaches sufficient weight to the circumstances that affect the visual and apparent phenomenon; and overlooks that two of the habitudes which he has discovered in the light, and which form the basis of his theory of a terrestrial ring, may be explained in this manner. Thus, that very striking circumstance that he has given of the light being somewhat to the north of the ecliptic when he was in north latitude, and the contrary when he was in south latitude, and which is abundantly borne out by his diagrams as evidenced in the compressed lines of the cone on one side, is accompanied also by this circumstance, that the side so compressed is almost invariably the acute angle with the horizon, where the vapours of the lower atmosphere would infallibly curtail the feeble exterior breadth of that, as compared with the opposite, side of the light.

In his theoretical considerations, again, page xix, Mr. JONES seems to overlook the con-

sequences of the zodiacal light medium, on the heliacal hypothesis, varying in density with its distance from the sun, as is visibly the case with the light; for, given an extreme rarity in our neighbourhood, and much greater comparative density, united with stronger illumination, in the neighbourhood of the sun, there will be hardly any sensible variation in the apparent phenomena seen about the sun from the earth, whether this be, or be not, immersed in the outermost portions. Some very slight symptoms, as I have described already, were given at Alta Vista, of the rare boundaries of the zodiacal light extending beyond the earth's orbit; and Mr. JONES's powerful eye would doubtless have shown them stronger still; but to him would of course have been intensified also the denser part within the orbits of Venus and Mercury; so that the question of the place of the mass of the light would remain where it was.

Towards the end of the American volume, a number of cases of lunar zodiacal light are given; but there again the effects of lunar dawn do not seem to have been fully allowed for; and while feeling the utmost admiration for the Rev. G. JONES, as an honest and most persevering observer, and while recommending to general attention those phenomena of lateral and latitude change which he considers that he has discovered, still I cannot look on his noble volume, but as in the light of a collection of unreduced astronomical observations; and as being therefore not yet altogether arrived at a point, for having theoretical views founded upon it.

(8.) *Lateral Refraction.*

Amongst the instructions communicated to me by the Admiralty were the two following:—

"The observer's attention should be directed to any instance of *lateral* refraction like that remarkable case described by HUMBOLDT as having occurred to him at Orotava."

"Observations to verify HUMBOLDT's remarks on the *lateral* oscillation of stars near the horizon."

These two passages may be assumed to refer to the phenomenon described at pp. 69 and 70 of BOHN's translation of vol. i. of Baron HUMBOLDT's celebrated 'Personal Narrative;' and alluded to again in his still more celebrated 'Cosmos,' vol. iii. SABINE's translation, pp. 55 and 56.

Thence it would appear that, not from Orotava, but from the "Ice cavern," at a height of 11,050 feet, on the Peak of Teneriffe, very shortly after daybreak on June 22nd, 1799, small stars 7 and 8 degrees high, towards the E.N.E., appeared to move about in a variety of abnormal ways, to an extent that was abundantly and even strikingly visible to the naked eye.

The learned Baron suggests that the approach of the sun, still many degrees below the horizon, disturbing the layers of the atmosphere, was the cause of the phenomenon he witnessed. In that case we might expect that the effect should be frequently and widely observable. This is, however, negatived by his own more numerous South American observations, as he himself mentions.

The same result follows from all my trials with the Sheepshanks telescope at Guajara, and the Pattinson equatorial at Alta Vista. At both stations Saturn was frequently observed near the eastern horizon shortly before sunrise, and was invariably found steady and well-defined, remarkably so, considering the circumstances.

No case of mirage, in the sense of violent disturbance of refraction, arising from grand natural causes, was ever seen by us on the mountain; and an exhibition of the sort is hardly to be expected in a breezy locality, almost isolated in the upper regions of the atmosphere. So that when Baron Humboldt mentions, that fluctuations amongst the eastern stars were seen by Prince Adalbert of Prussia, on the occasion of his ascending the Peak, and standing on the very site of his own remarkable observation, viz. the Ice cavern, one is inclined to ask, if either of those observers eliminated from what he saw, the effects of a vent of hot volcanic air in that immediate neighbourhood?

On my first visit to the Ice cavern, when standing outside in the day time at the usual resting-place, my attention was called by Mr. Carpenter, son of the Vice-Consul, to the apparent fumes of hot air distorting the rocks, not far off, in the E.N.E. direction from where we stood: and we clearly established, on subsequent visits, that the place must be a passage for volcanic action.

A correction then for these heated breaths, as a local disturbing cause, is essential to any observations of stars made, in their direction, from the "Ice cavern;" and while there is no evidence of the correction having been applied by either party, I am bound to add, after having had my attention directed officially to the matter,—that there are several grave inconsistencies in the accompanying parts of the narrative of the world-famous traveller, which sensibly detract from the importance of the case he has described.

CHAPTER IV.

PHYSICAL OBSERVATIONS.

(1.) *Radiation of the Sun by Thermometers.*

Towards obtaining the radiation of the sun, we were kindly lent by Mr. Airy two large black-bulb thermometers, having their bulbs enclosed in glass bells, and these furnished each with a syringe for the purpose of extracting the air. This part having been got to work very fairly, the instruments were used against each other, with the idea of one giving the true temperature of radiation, the other the temperature of shade. Each thermometer rested in its own packing box, placed on a short board; so that it might be conveniently tilted against a wall, to an angle of 90° with the incident solar rays, and was as much protected from the wind as possible. The lid of the radiation box was of course always open, while that of the shade box was closed, except when the reading was being made; and to obtain this with the greatest safety, the lid was sawed in two, so that the part covering the bulb never had to be opened at all; while to guard against the radiation penetrating through the lid, two boards were screwed to its upper surface

at a distance of half an inch apart, and had their faces covered with tinfoil. The box was further bored with holes above and below, to allow the circulation of air; but in spite of all these precautions, the shaded thermometer was influenced to about one-tenth to one-fifteenth of the existing radiation; I have therefore found it necessary in the reductions to reduce the shaded black bulb to the true shade temperature, by reference to the observations made more or less frequently with the dry bulb thermometer in the meteorological veranda.

Extensive series of observations were only made at Guajara, as accidents subsequently occurred to the instruments at Alta Vista and Orotava. Some important observations were, however, obtained at the latter stations, which may serve comparative purposes.

Maximum Radiation.

Observations to this end were made at Guajara on July 31, August 1, 3, 4, 5, 7, 8, 9 and 10. Rejecting July 31 and August 7, on account of the violent wind, dust-haze and clouds, we have the following quantities for the radiation, or the excess of the exposed black bulb above the thermometer in the shade:—

	August 1, at 11h 48m A.M.,	radiation $=102^\circ\cdot5$,	temperature $=67^\circ\cdot4$
	August 3, at 0 31 P.M.,	radiation $=111\cdot1$,	temperature $=65\cdot0$
	August 4, at 9 33 A.M.,	radiation $=121\cdot3$,	temperature $=56\cdot0$
	August 5, at 10 40 A.M.,	radiation $=120\cdot4+x$,	temperature $=57\cdot6$
	August 8, at 9 14 A.M.,	radiation $=113\cdot3$,	temperature $=60\cdot4$
	August 9, at 9 26 A.M.,	radiation $=120\cdot0+x$,	temperature $=58\cdot0$
	August 10, at 11 0 A.M.,	radiation $=116\cdot0+x$,	temperature $=62\cdot0$
Mean of 7 obs.	August 6, at 10 36 A.M.,	radiation $=\overline{114\cdot9+x\times\tfrac{3}{7}}$,	temperature $=\overline{60\cdot9}$

At Orotava, observations on August 27 gave—

At 11h 33m A.M., radiation $=99^\circ\cdot8+x$, temperature $=78^\circ\cdot2$,

and at Alta Vista, observations on September 1 and 2 gave,—

	Sept. 1, at 8h 46m A.M.,	radiation $=127^\circ\cdot8+x$,	temperature $=49^\circ\cdot2$
	Sept. 2, at 9 30 A.M.,	radiation $=127\cdot5+x$,	temperature $=49\cdot5$
Mean of 2 obs.	Sept. 1·5, at 9 8 A.M.,	radiation $=\overline{127\cdot6+x}$,	temperature $=\overline{49\cdot3}$

The expression $+x$ used above indicates that the mercury had risen through the whole length of the radiation thermometer-tube 178° or 179°, and was accumulating to an unknown extent in the small bulb which the maker had fortunately constructed there. A third radiation thermometer, kindly procured for us by Dr. LEE, at his expense, without such an upper bulb, was broken from this cause, I am sorry to say, on the first day of observation at Guajara, before we had become aware of the intense force of the direct rays of a mountain sun.

Of the value of x I can form but a very remote idea, perhaps 10° or perhaps 30°. The circumstance of there being such a quantity, while illustrating the powerful radiation of the region, prohibits any attempt at exactitude in the conclusions to be drawn: but we may notice the earlier hour of the day, at which the maximum would seem to take place, as the station is higher, as well as the greater intensity of the radiation: while, that the increase should appear to be nearly as great between Guajara and Alta Vista, as between the sea-level and Guajara, is a circumstance that bears notably on the question of its being practically advantageous to secure for astronomical instruments, heights greater still than any yet experimented on.

Radiation with the Sun on and below the Horizon.

At Guajara the radiation at night was found to be −11°·4, with a temperature of 52°; at sunrise −4°·0, with a temperature of 51°·2; and at sunset +12°·0, with a temperature of 59°·8, for the beginning of August.

That the excessive radiation of the day should heat up the air in the west is not to be wondered at; but that the sun's influence is so weak at rising, that the joint effect of its rays and the general eastern exposure should produce a negative effect, is very remarkable.

The individual observations are as follows:—

Night radiation,	August 1,	at 2h 28m A.M.,	radiation = − 5°·3,	temperature = 53°·3
Night radiation,	August 4,	at 1 43 A.M.,	radiation = −17·4,	temperature = 50·8
Mean . .	August 2,	at 2 6 A.M.,	radiation = −11·4,	temperature = 52·0
Sunrise radiation,	August 2,	. . . .	radiation = − 1·9,	temperature = 52·6
Sunrise radiation,	August 4,	. . . .	radiation = − 5·5,	temperature = 47·2
Sunrise radiation,	August 8,	. . . .	radiation = − 5·0,	temperature = 53·8
Mean . .	August 5,	. . . .	radiation = − 4·0,	temperature = 51·2
Sunset radiation,	August 1,	. . . .	radiation = + 6·8,	temperature = 58·8
Sunset radiation,	August 8,	. . . .	radiation = +17·2,	temperature = 60·8
Mean . .	August 5,	. . . .	radiation = +12·0,	temperature = 59·8

Horary Variation of Radiation.

For the purpose of obtaining the march of the radiation through the twenty-four hours, the observations of August 1 and 4 seem safer to be employed than any of the others; the first day having, however, the drawback, that the amount of radiation appears to have been lowered throughout the twenty-four hours, by the violent and unusual wind which was blowing at the time. This effect was strongest about sunrise; but for this period we are enabled to supplement the observations of August 1 by those of August 4, which appears to have been an unexceptionable day. As usual on such days, the mercury mounted soon after 9 A.M. above the graduation of the thermometer.

Obtaining, however, the ratio of the true radiation of August 4, and the wind-lowered radiation of August 1, during the period common to both, and applying it throughout, we have for the latter day the following tabular view of the progress of radiation + and — through the twenty-four hours, at the height of 8903 feet above the sea-level.

Radiation at Guajara on August 1, corrected.

Date.	Radiation.	Temp.	Date.	Radiation.	Temp.	Date.	Radiation.	Temp.
h m			h m			h m		
Aug. 1. 4 43 A.M.	— 5°·8	47°	Aug. 1. 1 13 P.M.	+123°·4	60°	Aug. 1. 9 43 P.M.	— 6°·3	49°
4 58 A.M.	— 5·6	47	1 28 P.M.	119·4	61	9 58 P.M.	6·1	50
At 5h 10m Sunrise			1 43 P.M.	123·1	61	10 13 P.M.	6·7	50
5 13 A.M.	— 3·0	47	1 58 P.M.	123·4	60	10 28 P.M.	5·8	49
5 28 A.M.	+ 7·0	47	2 13 P.M.	119·2	60	10 43 P.M.	6·3	49
5 43 A.M.	30·5	48	2 28 P.M.	121·2	60	10 58 P.M.	6·4	49
5 58 A.M.	49·0	48	2 43 P.M.	116·7	59	11 13 P.M.	6·0	48
6 13 A.M.	63·0	49	2 58 P.M.	112·3	60	11 28 P.M.	6·0	48
6 28 A.M.	73·0	49	3 13 P.M.	112·3	59	11 43 P.M.	6·4	48
6 43 A.M.	81·0	50	3 28 P.M.	110·7	59	11 58 P.M.	6·1	48
6 58 A.M.	88·0	50	3 43 P.M.	112·6	58	Aug. 2. 0 13 A.M.	6·0	48
7 13 A.M.	96·5	51	3 58 P.M.	109·5	59	0 28 A.M.	5·7	48
7 28 A.M.	99·0	51	4 13 P.M.	108·9	58	0 43 A.M.	4·7	48
7 43 A.M.	101·0	52	4 28 P.M.	103·2	58	0 58 A.M.	5·7	48
7 58 A.M.	103·0	52	4 43 P.M.	98·1	57	1 13 A.M.	5·7	48
8 13 A.M.	106·5	53	4 58 P.M.	93·6	56	1 28 A.M.	5·5	48
8 28 A.M.	109·0	54	5 13 P.M.	104·8	56	1 43 A.M.	5·5	48
8 43 A.M.	113·0	54	5 28 P.M.	104·7	55	1 58 A.M.	6·6	48
8 58 A.M.	116·1	55	5 43 P.M.	100·0	55	2 13 A.M.	5·4	48
9 13 A.M.	117·5	55	5 58 P.M.	93·0	54	2 28 A.M.	8·9	48
9 28 A.M.	119·0	56	6 13 P.M.	70·6	54	2 43 A.M.	5·8	48
9 43 A.M.	121·0	56	6 28 P.M.	46·9	53	2 58 A.M.	5·8	48
9 58 A.M.	124·2	57	6 43 P.M.	15·9	53	3 13 A.M.	5·2	48
10 13 A.M.	125·2	57	At 6h 49m Sunset			3 28 A.M.	5·1	48
10 28 A.M.	121·2	58	6 58 P.M.	+ 3·7	52	3 43 A.M.	4·3	48
10 43 A.M.	120·0	59	7 13 P.M.	— 1·5	51	3 58 A.M.	4·5	48
10 58 A.M.	124·0	59	7 28 P.M.	3·9	51	4 13 A.M.	5·4	48
11 13 A.M.	123·9	59	7 43 P.M.	6·7	51	4 28 A.M.	3·7	48
11 28 A.M.	144·0	59	7 58 P.M.	6·7	51	4 43 A.M.	3·4	48
11 43 A.M.	152·2	59	8 13 P.M.	6·4	51	4 58 A.M.	3·3	48
11 58 A.M.	152·4	60	8 28 P.M.	6·4	50	At 5h 11m Sunrise		
0 13 P.M.	146·4	60	8 43 P.M.	7·3	50	5 13 A.M.	— 2·0	47
0 28 P.M.	139·8	60	8 58 P.M.	6·3	50	5 28 A.M.	+ 1·7	48
0 43 P.M.	132·1	60	9 13 P.M.	6·1	50	5 43 A.M.	22·5	48
0 58 P.M.	+130·2	60	9 28 P.M.	— 6·0	49	5 58 A.M.	+43·0	48

With both temperature and radiation in the preceding Table, the object has been to exhibit what takes place on the most favourable day, not to take a mean of a number of days, good and bad; a plan which, however proper for the meteorology of the mountain, is not suitable to an inquiry into the heating power of the sun. There would have been advantage, doubtless, in taking a mean of a number of equally favourable days, if they could be had, partly to eliminate errors of observation, partly to eliminate the little varying asperities in the radiation curve, produced by natural influences: taking the quantities, however, as they stand, we may derive from them some useful hints for ulterior proceedings; as thus, that the next black-bulb thermometer prepared

for observation on a high mountain should be graduated to above 212°, such a temperature of radiation having been reached on Guajara in the middle of the day.

Towards the chief astronomical end of the Expedition, there is yet a more interesting conclusion to be drawn. The days of highest radiation are those of least temperature, and *vice versâ*; and this difference obtains in a signal degree on days when there was no visible disturbing action of wind or clouds. What then causes the radiation of one day to be greater than that of another, and the temperature less? The immediate agent appears to be the atmospheric dust, which has already been spoken of in the Astronomical Journal as so prejudicial a medium to telescopic vision, weakening direct light and multiplying general light; acting, in fact, by light precisely as the measures of radiation and temperature prove that it does by heat.

Hence, then, we may easily understand why, with the dust strata rising to a very limited height, say 11,000 feet, the small difference of altitude between Alta Vista and Guajara produced as great an increase in the radiation as did the great difference, nearly four times as great, between Guajara and Orotava. Hence also we are furnished with a very portable apparatus for ascertaining on a high and distant mountain the principal elements that produce a good astronomical site.

(2.) *Radiation by Actinometer.*

In the accurate determination of solar radiation for physical inquiries, the black-bulb must yield to Sir John Herschel's actinometer. That, in principle, has been stated by an able judge to be perfect; but the instruments themselves, as furnished by the best maker in 1856, according to our Teneriffe experiences, have not arrived at equal practical perfection. One of the most improved, the only one procurable at the time we left England, was very kindly lent by Mr. Airy, and with great generosity he ordered another to be constructed by the same artist as quickly as possible, and sent after us. Of these two, the internal thermometer of the first, when unpacked on Guajara, was found broken, and the actinometer-bulb had leaked, under circumstances of carriage, where barometers, thermometers, and even the gold leaves of an electrometer, and the silk fibre of a thermo-multiplier, travelled with perfect safety: the second actinometer, only arriving in Teneriffe at the conclusion of the summer, never got beyond the Consul's office in Santa Cruz; nevertheless—though admirably packed, first in its own box, and then with this placed in the centre of a much larger box, and filled in on every side with paper shavings—it had leaked, and to such an extent, that the fluid could not be brought into the graduated tube. No additional stock of fluid, and no solid materials for preparing it with water, had been supplied with either instrument. I mention these things only as indications of improvements to be made on the next occasion.

Trying to make up for the broken internal thermometer of the first actinometer on Guajara, by placing a small one, wrapped up in blue calico, under the glass covering the great blue bulb, I began to make observations on August 7; they were continued throughout the day, except during a cloudy interval. Wind and haze much interfered

with the results. August 8, however, opened more auspiciously, and I began before sunrise; and with the assistance of the mate and carpenter of the yacht, kept up observations continuously throughout the day, until the leaking of the bulb (which had begun again in the middle of the day, apparently from some effect of the heat twisting the wood, and finally splitting the glass) increased to such an extent, that the graduated tube could no longer be kept full.

Considering the state of the instrument, the only purpose that the observations can be made useful for, is to institute a rude comparison with the results of the black-bulb thermometers, which were simultaneously observed throughout the day. To facilitate this purpose, the actinometer results in the following Table have been multiplied by a factor, such as was found by trial, to make the sum of its degrees or divisions throughout the day, equal to the sum of the thermometer degrees. Each actinometer reading in the Table is the result of four "suns" and three "shades," corrected for temperature by the reading of the small inserted thermometer, and the Table given by Sir J. HERSCHEL in the 'Admiralty Manual.' Each black-bulb reading is the result of a pair of readings before and a pair immediately after each group of actinometer observations.

Comparison of Actinometer and Black-bulb results for Solar Radiation on August 8, on Guajara.

Time.	Actinometer radiation.	Black-bulb radiation.	Time.	Actinometer radiation.	Black-bulb radiation.	Time.	Actinometer radiation.	Black-bulb radiation.
h m	d	°	h m	d	°	h m	d	°
5 10 A.M.	− 1·8	− 2·8	9 6 A.M.	+88·2	+100·0	1 30 P.M.	+85·1	+71·0
5 14 A.M.	Sun rose.		9 28 A.M.	83·3	100·2	1 54 P.M.	85·1	80·8
5 32 A.M.	+22·5	+ 5·4	9 44 A.M.	85·0	99·0	2 24 P.M.	89·9	81·8
5 48 A.M.	36·3	26·8	10 0 A.M.	84·6	99·3	2 54 P.M.	84·2	76·0
6 10 A.M.	56·7	52·1	10 14 A.M.	84·2	98·2	3 24 P.M.	76·6	72·4
6 24 A.M.	59·8	61·2	10 34 A.M.	81·1	98·4	3 44 P.M.	83·7	71·9
6 40 A.M.	63·3	69·2	10 54 A.M.	78·8	93·7	4 0 P.M.	81·5	71·9
7 4 A.M.	68·7	57·6	11 14 A.M.	79·3	89·2	4 14 P.M.	71·8	70·4
7 20 A.M.	74·4	72·2	11 30 A.M.	74·4	87·0	4 32 P.M.	77·0	67·9
7 34 A.M.	77·1	79·0	11 44 A.M.	72·6	87·4	4 46 P.M.	75·3	64·5
7 56 A.M.	81·1	84·8	0 10 P.M.	94·4	87·0	5 4 P.M.	62·0	62·6
8 18 A.M.	82·8	88·0	0 34 P.M.	93·5	82·9	5 20 P.M.	63·3	58·3
8 32 A.M.	85·9	88·0	0 54 P.M.	79·7	74·0	5 44 P.M.	+54·5	+46·6
8 48 A.M.	+85·4	+95·6	1 14 P.M.	+84·2	+ 72·0		Actinometer broke down.	

Much as might be expected from the principle of the actinometer, it approved itself at sunrise as the more sensitive instrument; but the cause of the differences between the two instruments through the middle of the day is not equally plain; neither of them follows the law of altitude, and their differences from each other are far beyond errors of observation.

(3.) *Radiation of the Moon.*

For the particulars of observations with the excellent thermo-multiplier kindly lent by Mr. GASSIOT, reference may be made to volume 1, where the whole of them are entered, with notes of all attendant circumstances. Here it may suffice to state the resulting mean quantities.

At 22ʰ 27ᵐ . . .	+0°·9
At 22 29 . . .	+0·5
At 22 31 . . .	+0·9
Mean of three groups, including twenty-one readings . . .	+0·77

My naked hand, held at a distance of 3 feet, produced about + 7°·0, and at a distance of about 3 inches, produced about . . +20·0.

Again, on August 16th, or the day after full moon, and with that luminary at a height of 49°, the comparison of similar groups to those of the previous night gave,—

	Moon's heat.
At 22ʰ 43ᵐ . . .	+0°·2
At 22 45 . . .	+0·3
At 22 54 . . .	+0·2
At 22 56 . . .	+0·6
At 22 58 . . .	+0·5
At 23 0 . . .	+1·9
At 23 2 . . .	0·0
At 23 14 . . .	−0·1
At 23 16 . . .	+0·2
At 23 18 . . .	+0·8
At 23 20 . . .	+0·2
Mean of eleven groups	+0·44

The hand held at a distance of 18 inches in front of the cone, produced at $23^h\ 27^m$ a heat effect of $+9^\circ{\cdot}0$.

The "hand" observation of each night was rude, and merely to be sure of the sign accompanying heat; but the candle observations were made as carefully and accurately as possible; and as PRICE's candles appear to be very uniform in quality, it is possible that the value of the degrees of the thermo-multiplier may be accurately obtained in terms of FAHRENHEIT by further observations in this country. We shall then be able to state the moon's radiation in similar terms to the sun's. That the moon's radiation was fully sensible, the above observations will I think abundantly show; the only doubt is the respective weights to be given to the different series. The observations of the 16th having been affected by wind, and the first series on the 15th having been one-sided, I am inclined to weight them as follows:—

$$15^1=2,\ 15^2=4,\ \text{and}\ 16=1.$$

The simple arithmetical mean is, for the

Moon at 45° high . . . . . Radiation $=+0^\circ{\cdot}42$

When corrected for the weights it becomes . $=+0^\circ{\cdot}37$

Sir John Herschel has explained the inability of observers at low levels to obtain heat indications of the moon's rays, by considering that the heat is spent in dissipating vapours in the upper regions of the atmosphere, and so explains the preponderance of clear over cloudy nights at the time of full moon. On Guajara, there appeared to be a strong tendency to "upper" clouds during the several days preceding full moon, but on that night every particle of them disappeared; the lower clouds, however, were constant through the whole lunation. This does seem to confirm Sir John's idea; and to show too, that the moon's heat, though effective at great heights, is entirely expended before arriving at the lowest strata of cloud, 2300 feet above the sea. The elevation of the upper clouds which were apparently so effectually acted on, we had no means of accurately judging of, but I should suspect that it could not have been less than 15,000 feet; at that height then, or higher, should be made the next observations on the radiation of the moon.

(4.) *Lines in the Spectrum.*

Towards observing the black lines in the solar spectrum, we had a speculum to reflect sunlight, kindly furnished by Mr. J. Nasmyth, C.E., and an apparatus consisting of a prism, a fine adjustable slit placed in the focus of a 2-inch object-glass, and a telescope of the same size, with magnifying powers as high as 30, prepared for, and lent to us, by Mr. Airy. There was no angular measurement contemplated; only eye observation, and comparison of differences between the spectrum seen, and that engraved by Fraunhofer. To employ these instruments on Guajara, a small chamber, some 10 feet square, was built of rude stone, roofed in with planks and old canvas, and further covered with a quantity of "*retama*" branches to keep out every particle of the sun's light: while a square tube of wood, 5 feet long, with a moderate aperture at the end, was thrust through the wall in the direction of the speculum mounted on a small stone pier outside. In this manner a considerable degree of darkness was secured, even when the sun's rays were being reflected into the instrument.

A cursory examination of the spectrum showed much general correspondence with Fraunhofer's view as to the principal lines; but so great discordance as to detail, that I thought it better to proceed on an entirely independent footing, and make original drawings of what I saw; and when well satisfied with them, to compare them with the engraving. One evening trying the sun unusually low, and finding new features worth following up further than could be done while using the reflected ray from the speculum, I took the prism apparatus out into the open air, and by means of a theodolite stand and photographic black bag, was enabled to continue the observations until the sun set at the usual mountain zenith distance of 91° 11′. These direct observations of the sun were repeated on many occasions with the sun both east and west. The lunar spectrum and that of the blue sky were also similarly examined.

So far for the Guajara experiences. At Alta Vista a similar optical dark room was prepared; but profiting by hints procured from the *direct* use of the line instrument at

low altitudes, I tried it on the sun at mid-day in the same manner; when an immense increase in the number and definition of the black lines at the violet end took place. With the reflected ray, the two bars of H could but just be discerned as faint nebulous streaks, B, C, and D being as sharp and as black as silver wires in a telescope; with the direct ray the individual lines composing the bars of H could be distinctly separated, and many lines appeared indistinctly in the space beyond. The conclusion thence to be derived was, unfortunately, that our particular speculum did not reflect the violet end of the spectrum; and our observations were therefore not comparable in that part, even if they were in others, with standard observations elsewhere. The discovery was made too late to enable a *direct* determination to be made for Guajara, but the method was employed for Orotava when we returned there from the mountain a few days after.

Red End of the Solar Spectrum.

In the accompanying Table (Plate XXXV.) are arranged the whole of the drawings of the red end of the spectrums that were taken at the three stations, on the same scale as FRAUNHOFER's justly celebrated Munich engraving. The times and circumstances of the observations being appended, will enable any one to judge of the reality of the facts purporting there to be represented.

Bearing in mind that great accuracy of position is not pretended, and that though much care was bestowed on the general appearance, thickness, and definition of the lines, the shortness of the time available was entirely inadequate to procuring a good drawing, and that several of the diagrams should be employed together in deducing a result,—we may proceed to the examination. Comparing the eleven Tenériffe spectrums of the sun with FRAUNHOFER's, we can only assume identity in place of the lines A, *a*, B, C, D, E, and *b*: everything else appears differently. Of this difference the prevailing feature appears to be, that whereas FRAUNHOFER's spectrum stretches to beyond A, which is seen by him as a clear and distinct line,—he gives none of the numerous broad bands and groups of lines between A and *a*, and *a* and B, that were visible on the mountain and below, whenever A was quite or nearly visible.

From the fact of FRAUNHOFER's spectrum including A, we might be entitled to expect from the Teneriffe observations, that it represents the sunset appearance (see No. 10); but then how can the omission of the broad bands of lines between A and B, and C and D, and especially those beyond D, be explained? If, on the contrary, the absence of those marked bands is to be regarded as a proof that a high spectrum was intended, Nos. 1, 2, and 3 indicate that A should not be seen in such a position. Again, while the spaces between A *a* and *a* B are blank in FRAUNHOFER, and well filled in Teneriffe, he has some lines between B and C, a compartment always remarkably empty with us.

Comparing the Teneriffe observations *inter se*, we may assume 2 and 3 as giving a near approach to a zenith solar spectrum, and 4, 5, 6, 7, 8, 9, 10 as giving the effects superinduced by the sun being seen through a greater thickness of the atmosphere by

lowering in altitude only, all the observations being made at the same station, viz. Guajara at a height of 8903 feet.

A zenith spectrum then, at that height and with the particular apparatus employed, would appear to begin between *a* and B; and, excepting the lines C and D, to have nothing noticeable between B and E. A horizontal spectrum, on the other hand, station and instrument remaining the same, begins outside A, has numerous powerful bands of lines between A and B, but none between B and C; and while C has not increased in thickness, B has more than quadrupled its size, maintaining full sharpness and definition. Again, a certain excessively fine line, at the distance of B to C beyond C, has grown to many times the thickness of the latter, and is accompanied by a broad and marked band of finer lines. A more extensive increase still is perceived in the innumerable lines between C and D, and immediately beyond D. Of these variations from a zenith spectrum, as observed phenomena, there is no doubt; for the series of drawings, taken quite independently, are found on being now brought together, to confirm each other in the result of the growth of these lines with the zenith distance. The observations of August 9 are the most important to this end: there were three drawings obtained the same evening, and the lines grew visibly under my eyes: the red end *apparently* lengthened out from B to A; additional lines were seen every succeeding moment, and the old ones became better defined, causing nebulous bands at 85° zenith distance to become groups of fine black lines at 91° zenith distance. Looking at the same time to the notes of colour, the red *seems* continually to have grown, to the final exclusion, at 91° zenith distance, of yellow as a pure colour, orange merging at once into green.

Contrasting now No. 1 with Nos. 2 and 3, we find, if we may overlook the two latter having been observed by reflected, instead of direct rays, that a zenith spectrum at the sea-level differs most notably from one on the mountain, by the greater extent of the red end visible, and by the increased number of lines; and that, though it shows some approximation to a low-sun mountain spectrum, it has some radical differences therefrom.

Professor Stokes indeed suggests, that the deficiency of the red end of my high-sun mountain spectra may be due to the more luminous rays extinguishing the faint red; and that if the former had been absorbed by a cobalt-blue glass, or the extreme red separated by refraction through a second prism, A might have been seen; just as in fact it was seen with the low-sun spectra, when the atmosphere acted the part of a suitable absorbing medium; and the suggestion is of extreme value for future experiments, though it is proper to state, that on Teneriffe the magnifying power employed was such, as necessarily to throw the brightest part of the spectrum out of the field of view when the extreme red was under examination.

Red End of Sky Spectrum.

No. 13 appears to show that a zenith sky spectrum on the mountain with the sun in

the neighbourhood, does not differ much from the solar spectrum; but Nos. 14, 15, and 16 show that such a spectrum, with the sun somewhat low, as 20°, has neither lines nor light at the red end, but that they gradually increase as we try the lower regions of the sky, showing there the remarkable multitude of lines beyond D.

Taking together the whole of the sky spectrums, 12 to 17, and comparing them with those of the sun, we find that C is not marked in circumstances where it might be expected; and when it does appear, it is overpowered by the "growing" line in the direction of D. Likewise D is overpowered by the numerous broad bands beyond it; so that when the spectrum is seen faintly, those variable lines might easily be mistaken for C and D, and a greater degree of identity might thence be considered to prevail between the sun and sky spectrums than actually obtains.

Red Ends of Lunar Spectrums.

The moon was not well situated for spectrum observations, though drawings were obtained on August 13th and 15th, at altitudes of 25° and 38°; and at times, two days before, and on the night of, the full moon.

The most striking feature was the blood-red character of the red end; beyond the extreme intensity of this colour, the other tints had nothing notably different from a sun spectrum. Notwithstanding the amount of red light, no lines could be perceived there: in this circumstance was a striking difference to the low sun spectrums, where, as the red became predominant, the number, size and visibility of the lines in the red increased also. The first line identified in advancing from the red end, was the growing line between C and D; from thence was a long blank space until three fine lines near E were seen, then E and F. These observations were direct.

Violet End of the Spectrum.

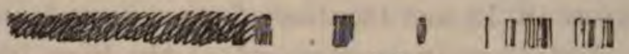
Eight drawings of the violet end of the sun's spectrum, two of the sky's, and two of the moon's were obtained; but I do not think them worth engraving here, as most of them labour under the untoward effects of the speculum. It may suffice to remark, that at Guajara, the vertical sun spectrum terminated beyond H, while the horizontal sun spectrum was so shortened at that end as to terminate between H and G.

Again, comparing a high sun spectrum at the sea-level with a similar one at Alta Vista, 10,702 feet high, both observed direct, it was found that while in the former the spectrum terminated immediately beyond H, and the two bars of H were nebulous, in the latter the spectrum extended beyond H to three times the distance of its bars asunder: the two said bars also lost all their nebulosity, being clearly resolved into their component lines; many fine clear lines were seen between them, and many appeared nebulously in the space beyond. In the sky spectrums, and more particularly in those of the moon, the prominence of G was remarkable; next came F, while H was nearly if not quite invisible.

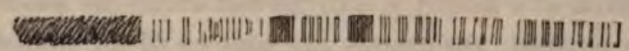
(5.) STOKES'S *Spectrum.*

At Guajara many experiments were made in the dark optical room with a quartz train, lent by Professor STOKES, but they are all unfortunately faulty, by reason of the speculum employed.

Of two large drawings that were made on August 10 and 12, near noon, one terminates at the limiting line in a drawing of the extended spectrum furnished to me by Professor STOKES, the other contains two lines more. What would have been the result had the direct solar light been employed, may be gathered from the two subjoined drawings of the violet end of the ordinary spectrum, as seen with the glass apparatus at Alta Vista: they were taken on the same day, September 12, and within a short time of each other.


Reflected.

nebulous. nebulous.


Direct.

clearly resolved.

The mean, then, of the observations on August 10 and 12 shows that a little more of STOKES'S new portion was seen on the mountain than has been seen near the sea-level, notwithstanding the drawback of the speculum; while if we add for that, what we are fairly entitled to do from the two above views of H, direct and reflected—we may assume that there is a much greater amount of the more refrangible rays in the sun's light in the upper, than in the lower regions of the atmosphere.

This result is confirmed by another observation. The spectrum formed by the quartz train was frequently photographed on a collodion plate, and the image so formed was found identical with that presented to the eye by uranium glass. Taking then powerful photographic effects as an indication of the abundance of rays of high refrangibility, it is very remarkable to find, on looking over my landscape photographs, about 120 in number, and pretty nearly equally divided between the three stations, Orotava, Guajara, and Alta Vista, that not only is there always a greater intensity, but that the distances came out invariably much better, in proportion as the station is higher.

At the height of 10,702 feet, the eastern wall of the crater of elevation, distant some four miles, is given with all the detail that the eye could appreciate at the time; while at the sea-level on the finest mornings, and when the cliffs above Realejo, not three miles distant, were vividly illuminated by the morning sun, and casting on one side dense and dark shadows—yet the photographs would persist in giving nothing but the mass of the mountain in one uniform tint, save only one remarkably white stratum. This at least testifies to the focus having been exact; while the detail of things in the foreground is represented with such vigour, as to prove that the quality of the photographic material was by no means deficient.

In place of showing the mountain with all the intense detail brought out to the eye by the sun shining strongly on its rocky slopes, the appearance was rather as if that luminary were on the other side, and we only saw the shaded form of the ridge. Or

it might be likened to the effect that would have taken place to the eye, had the mountain been seen through a much greater depth of atmosphere, or had that atmosphere been thicker, as with a diffusion of smoke throughout it.

(6.) *Magnetometer.*

For the purpose of obtaining observations of magnetic intensity, a vibrating needle was kindly supplied by Mr. AIRY, together with some fine aloe fibres, procured by himself in Madeira. On opening the boxes at Guajara in the beginning of August, at which time most of our instruments were suffering from the extreme drought, the mahogany stand was found to have so shrunk on the thick plate-glass cover of the needle area, as to fix it in completely. By cutting away the wood, however, around the glass, it was got out, and on August 10, 12, and 13, observations were made at that station, 8903 feet high. On August 24, observations were made at Alta Vista, 10,702 feet high, and on August 27 in Orotava, at a height of only 25 feet above the sea-level.

The plan of observation pursued, was exactly the same at all the stations: the needle was set swinging at a large angle, by advancing a knife, and was then observed at every tenth vibration, through 300 vibrations; the mean angle of a series was always near 45°; and a correction has been since applied to reduce the readings exactly to that angle. The times were observed by a sidereal chronometer.

Magnetometer.

No.	Date.	Locality general.	Locality particular.	Mean of thirty observations of ten seconds each.	Mean for each station.
	h m			sec.	
1	Aug. 11, 4 10 P.M.	Guajara	On a pedestal of the trachyte stone of the hill, and under the shade thrown by a deal plank	38·02	s. 38·04
2	Aug. 11, 4 46 P.M.	Guajara	Ditto	38·05	
3	Aug. 12, 5 40 A.M.	Guajara	Ditto	37·91	
4	Aug. 12, 6 10 A.M.	Guajara	Ditto	37·90	
5	Aug. 13, 9 0 A.M.	Guajara	Ditto	38·31	
		Altitude= 8,903 feet			
6	Aug. 24, 10 30 A.M.	Alta Vista	In shade of large block of black lava, N.E. of station	37·72	38·45
7	Aug. 24, 11 25 A.M.	Alta Vista	In shade of lava stream, to S. of station	39·05	
8	Aug. 24, 3 20 P.M.	Alta Vista	In empty room in station	38·58	
		Altitude=10,702 feet			
9	Aug. 27, 8 0 A.M.	Orotava	Basalt step of Inn yard...	37·54	37·73
10	Aug. 28, 7 35 A.M.	Orotava	Basalt step of Inn yard	37·67	
11	Aug. 28, 8 20 A.M.	Orotava	Centre of Inn yard	37·99	
		Altitude= 25 feet			

It is satisfactory to find the means of all the observations at each station giving a continually increasing time of vibration with the altitude, but I do not attach importance to the result, because,—1st, a difference far exceeding the whole effect of height appears to have been caused at Alta Vista by change of position in the instrument with reference

to the lava streams; and 2ndly, the rocks at the several stations were found to be slightly magnetic in hand specimens; the most powerful of them was one from Guajara, consisting of obsidian and trachyte in alternate laminæ: the origin of the specimen was a small crater about 100 feet below the station, and the material was present there in large masses.

(7.) *Polarimeter.*

A polarimeter, devised by Mr. AIRY, constructed and kindly lent by him for the Teneriffe experiments, was employed frequently; but not, I find now, and am sorry to say, with so much discrimination as would have been advisable.

The instrument consists of a principal tube, capable of being turned round its own axis, and of being pointed in any direction, its angular distance from the sun being given by a shade-bar on a graduated semicircle; this semicircle being mounted on a collar, which is free to turn, or can be clamped on the tube. The light which passes down from the sky through the tube falls on a bundle of reflecting glass plates, supported just under the tube's lower end, on a transverse axis, carried by two arms projecting from the sides of the tube. This axis allows the glass plates to have their inclination varied at pleasure, with reference to the tube's incident light, and has connected with it a mechanism, by which an eyepiece, armed with a NICOL's prism and plate of calc-spar, is always carried in the direction of the reflected light; graduated arcs being added at the side, for reading off the angles of incidence and reflexion.

Now with this apparatus, when its eyepiece is at the angle of complete polarization, the polarization produced by the glass plates is necessarily shown, and the corresponding coloured rings exhibited; but at angles of such imperfect polarization, that their diminution of the coefficient of etherial vibrations in one plane, is only equal to the atmospheric diminution of the coefficient of vibrations in the transverse plane, all traces of polarization disappear. Beyond those angles, of course, the complementary rings due to the polarization of the atmosphere or blue sky are seen.

The practical method of observing was therefore, starting from a mean angular position of the eyepiece, giving great intensity of glass-plate polarization, slowly to decrease the angle between incidence and reflexion, until the vanishing point of the rings, or the passage of the one set into the other, was just arrived at: the readings being then noted, the angle was again opened out, past the maximum of glass-plate polarization, until the vanishing point on the other side was arrived at, and duly read off on the graduated arcs; when half the angular distance between the two vanishing points was set down as "inverse intensity of sky polarization."

It is here supposed that the instrument was previously adjusted, by turning the tube round its axis, so that the plane of reflexion was perpendicular to the plane of sky polarization, which was ordinarily assumed to pass through the sun; but the instrument itself is competent to point out whether this adjustment be made, since otherwise the rings do not wholly vanish at any incidence.

When the tube was pointed to within 20° of the sun, or its opposite point, the sky polarization was so weak, that the rings due to the polarization of the glass plates were

never lost sight of through the whole extent of angular motion possible to the eyepiece and its carrying bar, about 130°; and the results therefore, for that region, must be negative. But for greater solar distances, reckoning from the equator of a sphere having the sun in one of its poles, or in terms of "sky declination," we have the following results at the three stations noted.

Polarimeter.

Guajara.

Date.	No. of obs.	Sky decl.	Inverse intensity of sky polarizⁿ.
1856. Aug. 14.	1	1°	52·1°
	1	4	41·0
	1	6	42·0
	1	9	41·5
Exceptional day, abnormal local cloud suspended over station.			
Aug. 16.	10	3·8	28·4
	10	10·1	25·6
	10	13·3	27·7
	10	18·1	32·2
	10	26·1	36·2
	10	33·8	43·0
	10	40·5	49·7
	10	46·7	54·2
	5	56·8	63·9

Alta Vista.

Date.	No. of obs.	Sky decl.	Inverse intensity of sky polarizⁿ.
1856. Aug. 23 to Sept. 11.	10	1·2°	23·6°
	10	3·7	24·6
	10	5·7	26·4
	10	7·7	25·6
	10	10·2	26·8
	10	13·8	28·0
	10	16·0	27·6
	10	19·9	30·7
	10	23·5	32·2
	10	26·2	33·3
	10	28·5	35·7
	10	32·8	40·6
	10	36·3	43·0
	10	40·1	46·0
	10	45·0	50·2
	10	49·5	56·4
	10	53·8	59·1
	10	59·6	63·2

Edinburgh.

Date.	No. of obs.	Sky decl.	Inverse intensity of sky polarizⁿ.
1857. Oct. 30.	4	0·0°	20·8°
	6	5·0	20·2
	4	12·5	22·9
	2	22·5	28·0
Nov. 19.	12	0·0	33·4
	4	5·0	34·8
	4	10·0	37·2
	3	15·0	38·9
	5	25·0	37·8
Sky clear from clouds, air calm, but filled with smoke.			
Nov. 20.	4	0	21·1
	4	5	21·8
	5	9	22·3
	2	15	23·2
Nov. 24.	2	0	21·2
	2	5	21·5
	2	10	22·2
	1	15	23·1

Before comparing the above observations, we must reject the Guajara series of August 14, as vitiated by an unusual local cloud; and the Edinburgh series of November 19, on account of the evidently prejudicial effect of smoke nearly uniformly diffused in all the upper air. To test this point still further, the following series for intensity in the sky equator was taken, everything remaining the same but the altitude of the principal tube; and when this was directed at 10° to the strongly smoky band on the horizon, there was evidently a sudden decrease of the intensity of the polarization, shown as before by an increase of the instrumental numbers:—

Altitude 45°, inverse intensity of sky polarization = 31·7°
Altitude 20, inverse intensity of sky polarization = 32·3
Altitude 15, inverse intensity of sky polarization = 32·9
Altitude 10, inverse intensity of sky polarization = 41·0

Comparing then the three normal Edinburgh days with the mean of the whole Alta Vista period, the polarization would appear to be rather stronger below than above, but at either station to follow the law of maximum intensity at or near 90°.

The next step is a more delicate one, namely, to compare the intensity in declinations towards, and from, the sun. For this purpose, of the three normal Edinburgh days, October 30 may be taken by itself, and the two shorter series on November 20 and 24 may be taken together; we then have two series, both indicating the maximum of polarization in about 98° of sun polar distance, thus—

October 30.			November 20 and 24.		
Sun. Polar dist.	No. of observations.	Inverse intensity of sky polarization.	Sun. Polar dist.	No. of observations.	Inverse intensity of sky polarization.
75°	1	26°·0	°		°
80	1	24·5	80	3	23·5
85	1	20·5	85	3	21·6
90	2	20·5	90	6	21·1
95	3	19·8	95	3	21·7
100	1	20·5	100	3	21·7
105	1	20·5	105	3	28·1
110	1	25·0			
115	1	26·0			

At Alta Vista the observations of September 10 appear most suitable for this purpose, and give a maximum intensity about 82° distance from the sun, thus—

Sun. Polar dist.	No. of observations.	Inverse intensity of sky polarization.
64°·0	26	30°·1
70·0	27	26·1
80·5	27	26·2
85·0	21	25·1
91·7	25	28·8
100·8	25	29·6

A series was also taken at Alta Vista on September 10 and 11, to try the intensity in different planes, the normal plane employed, designated on the instrument by 90°, being when the eye-piece moved in a plane at right angles to the sun-shade plane.

Plane employed.	No. of observations.	Inverse intensity of sky polarization.
−82°·5	18	28°·5
−85·0	18	27·3
−87·5	18	26·3
90·0	17	26·7
+87·5	19	26·8
+85·0	19	27·1
+82·5	18	28·4

These observations may be taken as establishing 90° as the true plane; nine observations in Edinburgh on October 30, gave no effect from +80° to −80° at all equal to the error of observation, which appeared to increase with the distance from 90°.

The plane was also attempted to be ascertained from the estimated amount of rotation

observed in the passage of the black into the white cross, both at Alta Vista and at Edinburgh.

Alta Vista.			Edinburgh.		
Plane.	No. of observations.	Amount of rotation.	Plane.	No. of observations.	Amount of rotation.
$-82°.5$	18	$4°.3$	$-80°$	1	$4°$
-85.0	18	2.0	-85	1	1
-87.5	18	0.5	-87	1	1
90	17	0.6	90	1	0
$+87.5$	19	1.9	$+87$	1	2
$+85.0$	19	3.9	$+85$	1	3
$+82.5$	17	6.1	$+83$	1	3
			$+80$	1	5

The point of least rotation would seem at either place to be from 1° to 3° on the — side of 90°, or to indicate that the true plane passes through the part of the blue sky under examination,—the observer's eye,—and, for the third point, a spot a little *above* the sun; an indication of the neutral points of ARAGO, BABINET, and BREWSTER.

CHAPTER V.

METEOROLOGICAL OBSERVATIONS.

Appended to the Meteorological Observations and their reductions in vols. 2, 3, 4 and 5, there are such full accounts of the instruments, observers, and methods of reduction, that nothing remains to be done here but to collect the results for the three stations; the first of which, for the sea-level, is the Titania yacht, in Santa Cruz roads; the second, at 8903 feet of elevation, is Guajara; and the third, at 10,702 feet of elevation, is Alta Vista.

(1.) *Hourly Variations.*

From the means of three days of hourly observations in the 'Titania,' two days at Guajara, and two at Alta Vista, the following Table has been prepared, showing the corrections to reduce the barometer, thermometer, and depression of the dew-point, observed at any one hour, to the mean for the whole twenty-four hours.

By reason of the very short period that these observations extend over, the results are rough, with those accidental variations which the employment of a greater number of days would have tended to clear away, and which might have been somewhat smoothed down, quite legitimately, in making out a general table; but I thought it better, on the whole, to give the actual numbers resulting from the arithmetical operations, as being more adapted to serve all the purposes suggested for the Expedition.

The readings of the barometer, it may be here remarked once for all, have in every case been reduced to 32°, and to the Greenwich standard; and the depressions of dew-point and elasticities of vapour have been calculated by Dr. APJOHN's formula for observations of wet- and dry-bulb thermometers, whose index errors have been carefully applied in every case.

TABLE I.

Hour.	Sea-level. Barometer.	Sea-level. Dry-bulb thermometer.	Sea-level. Depression of dew-point.	Guajara. Barometer.	Guajara. Dry-bulb thermometer.	Guajara. Depression of dew-point.	Alta Vista. Barometer.	Alta Vista. Dry-bulb thermometer.	Alta Vista. Depression of dew-point.
h	inch.	°	°	inch.	°	°	inch.	°	°
6 A.M.	—·006	+2·1	+1·4	—·007	+3·7	—1·4	+·030	+4·0	+ 1·0
7 A.M.	—·011	+1·1	+1·1	—·008	+2·4	+0·6	+·004	+1·0	+ 0·9
8 A.M.	—·012	—0·2	—0·3	—·020	—0·4	—3·0	—·014	—2·4	— 2·6
9 A.M.	—·026	—0·7	+0·1	—·036	—2·6	—3·4	—·019	—4·1	— 0·9
10 A.M.	—·029	—0·6	+0·6	—·042	—5·0	—8·4	—·030	—6·8	— 4·2
11 A.M.	—·024	—1·2	+0·2	—·040	—7·2	—9·9	—·026	—7·2	— 4·2
0 P.M.	—·008	—2·3	—1·1	—·036	—7·5	—5·6	—·019	—7·0	— 4·4
1 P.M.	·000	—2·7	—1·6	—·027	—8·2	—7·6	—·016	—7·5	— 9·2
2 P.M.	+·008	—3·3	—3·5	—·024	—8·8	—5·9	—·006	—8·4	—10·2
3 P.M.	+·015	—3·3	—3·5	—·012	—8·0	—7·2	+·008	—7·3	— 9·2
4 P.M.	+·030	—2·7	—4·0	—·006	—6·9	—3·9	+·013	—5·1	— 6·5
5 P.M.	+·021	—2·3	—2·9	+·002	—4·0	—3·2	+·017	—0·6	— 3·7
6 P.M.	+·013	—1·9	—2·2	+·002	—1·2	0·0	+·010	+1·8	— 2·0
7 P.M.	+·001	—0·4	—1·0	—·003	+0·7	+2·4	+·005	+2·7	+ 0·4
8 P.M.	—·011	+0·7	+1·0	—·010	+1·0	—0·6	·000	+3·0	+ 2·2
9 P.M.	+·021	+0·7	+1·0	—·014	+3·4	+1·6	—·012	+3·8	+ 4·8
10 P.M.	—·029	+1·2	+1·8	—·008	+3·8	+3·2	—·016	+3·8	+ 5·7
11 P.M.	—·019	+1·4	+0·9	—·004	+5·2	+5·4	—·014	+3·8	+ 7·6
0 A.M.	—·004	+1·5	+1·2	+·012	+5·2	+4·5	—·013	+4·3	+ 5·8
1 A.M.	+·010	+2·0	+1·7	+·027	+5·7	+6·5	—·004	+4·9	+ 8·7
2 A.M.	+·019	+2·3	+2·3	+·039	+6·1	+7·9	+·013	+4·4	+ 7·4
3 A.M.	+·025	+2·4	+2·7	+·055	+7·1	+9·1	+·024	+5·4	+ 7·4
4 A.M.	+·025	+2·8	+2·6	+·057	+7·5	+9·1	+·030	+6·2	+ 3·6
5 A.M.	+·029	+3·1	+2·3	+·058	+7·7	+9·8	+·042	+6·1	+ 3·0

TABLE II.

Comparison of Hourly Variations at the three Stations.

	Sea-level. Time.	Sea-level. Deviation from mean of twenty-four hours.	Guajara. Time.	Guajara. Deviation from mean of twenty-four hours.	Alta Vista. Time.	Alta Vista. Deviation from mean of twenty-four hours.
		in.		in.		in.
Barometer pressure, maximum A.M.	10 A.M.	·029	10 0 A.M.	·042	10 A.M.	·030
Barometer pressure, minimum P.M.	4 P.M.	·030	5 30 P.M.	·002	5 P.M.	·017
Barometer pressure, maximum P.M.	10 P.M.	·029	9 0 P.M.	·014	10 P.M.	·016
Barometer pressure, minimum A.M.	5 A.M.	·029	5 0 A.M.	·058	5 A.M.	·042
Daily range	......	·059	....	·100	......	·072
		°		°		°
Temperature, maximum	2 P.M.	3·3	2 0 P.M.	8·8	2 P.M.	8·4
Temperature, minimum	5 A.M.	3·1	5 0 A.M.	7·7	4 A.M.	6·2
Daily range	......	6·4	....	16·5	......	14·6
		°		°		°
Depression of dew-point, maximum	4 P.M.	4·0	11 0 A.M.	9·9	2 P.M.	10·2
Depression of dew-point, minimum	3 A.M.	2·7	5 0 A.M.	9·8	1 A.M.	8·7
Daily range	......	6·7	....	19·7	......	18·9

The chief purpose of the above Tables is to serve in the reduction of isolated observations to the daily mean: we may however at once draw some interesting conclusions with reference to low and high stations. Thus at the level of the sea there are two regular and equal tides in the barometer, but on the mountain there is a tendency to lose the afternoon minimum and evening maximum, and to show in the twenty-four hours only one unequally-sided wave, having its minimum at 5 A.M., and its maximum at 10 A.M.

On the mountain the daily range of the barometer is rather larger than at the sea-level; and, as with the wave feature already adverted to, is greater at 8903 feet, than at 10,702 feet. Similarly, with the daily range of the temperature and the dew-point, they are nearly three times greater on the mountain than below, but are rather greater always at Guajara than at Alta Vista.

In the epochs and characteristics of the *elevated* barometric maxima and minima, there will be immediately perceived a resemblance to the effects of applying the usual correction for "elasticity of vapour," to deduce the pressure of dry atmosphere at a lower station*; and on introducing the same correction (viz. the elasticity of vapour due to the temperature of the dew-point), the above quantities become, for the

	inch.	inch.	inch.	inch.
Sea-level . .	+·008	−·004	+·008	−·013
Guajara . .	+·060	−·009	+·023	−·072
Alta Vista . .	+·012	+·004	+·004	−·021

Further illustrations of the effects of height in the hourly variations are given in Plate XXXVI., where the hourly readings of the instruments on a corresponding day above and below are graphically represented.

(2.) *Daily Means.*

Towards procuring the daily means of barometer, thermometer, and dew-point, there were never less than four observations each day on board the yacht, and seldom less than three on the mountain; these being corrected by the foregoing Tables of hourly variations, and meaned, are exhibited in the following Tables, and part of them in Plate XXXVII.

* See Mr. J. Johnson's "Oxford Observations" for 1856.

Table I.

Daily Means of Observations of Meteorological Journal at Sea-Level.

Date.	Barometer, corrected daily mean.	Dry-bulb, corrected daily mean.	Depression of dew-point, corrected daily mean.	Temperature of sea-water.	Date.	Barometer, corrected daily mean.	Dry-bulb, corrected daily mean.	Depression of dew-point, corrected daily mean.	Temperature of sea-water.
	inches.	°	°	°		inches.	°	°	°
1856, July 13.	30·046	73·3	12·0	69·9	1856, Aug. 19.	30·011	75·0	10·3	
14.	29·986	74·6	13·2	69·8	20.	30·058	73·2	10·4	72·5
15.	30·051	75·5	17·4	70·1	21.	30·109	73·6	9·4	72·8
16.	30·106	73·4	14·8	70·3	22.	30·125	73·4	10·8	
17.	30·069	71·0	15·1	69·9	23.	30·038	72·6	12·8	
18.	30·038	72·4	13·7	69·8	24.	30·008	72·8	13·4	
19.	30·045	73·5	7·6	70·7	25.	30·015	74·3	10·8	73·0
20.	30·035	74·1	7·2	71·8	26.	29·985	75·2	15·9	
21.	30·003	72·6	7·0	70·9	27.	29·925	77·8	19·6	
22.	30·001	72·0	10·0	71·8	28.	29·965	76·1	12·0	
23.	30·055	72·1	13·2	70·5	29.	30·019	73·6	6·0	74·0
24.	30·117	72·0	12·3	71·0	30.	30·015	75·2	6·5	75·0
25.	30·153	71·7	12·0	70·8	31.	29·993	74·1	7·0	74·8
26.	30·133	72·5	13·4	71·0	Sept. 1.	29·921	74·0	9·4	
27.	30·046	74·5	16·5	71·5	2.	30·035	74·8	10·8	
28.	29·963	75·4	16·4	72·5	3.	30·080	73·6	8·8	73·8
29.	29·951	72·9	8·2	72·0	4.	30·093	74·3	12·4	73·5
30.	30·006	73·0	8·0	70·5	5.	30·090	74·0	13·0	73·8
31.	30·044	73·1	8·6	72·0	6.	30·123	74·8	11·4	
Aug. 1.	30·031	71·3	7·1	71·8	7.	30·201	73·7	8·8	
2.	30·003	72·0	8·1	72·0	8.	30·145	73·1	12·1	74·0
3.	30·035	72·6	13·6	72·0	9.	30·081	73·1	12·5	
4.	30·106	74·2	12·2		10.	30·105	73·3	10·6	
5.	30·125	72·8	11·4		11.	30·057	74·4	13·3	
6.	30·145	73·2	13·5	71·8	12.	29·991	73·6	10·1	
7.	30·141	72·7	11·1		13.	30·008	73·6	8·6	75·0
8.	30·080	72·6	13·4		14.	30·083	73·4	9·6	
9.	30·040	72·5	13·7		15.	30·119	78·4	12·5	
10.	30·044	72·2	11·4	72·0	16.	30·138	78·8	17·3	74·2
11.	30·041	75·5	12·8	72·2	17.	30·034	78·3	17·0	
12.	30·019	74·6	12·2		18.	30·024	77·2	13·1	
13.	30·029	73·3	10·6		19.	30·109	75·6	7·3	
14.	30·021	74·8	12·0		20.	30·110	77·0	12·4	75·0
15.	30·001	74·5	7·6		21.	30·076	74·8	9·2	
16.	30·017	74·1	9·6		22.	30·115	73·7	9·0	
17.	30·020	74·8	15·2		23.	30·163	74·7	12·7	74·6
18.	30·024	73·9	9·8						

TABLE II.

Daily Means of Observations of Mountain Meteorological Journal at Guajara Station.

Date.	Barometer, corrected daily mean.	Dry-bulb, corrected daily mean.	Depression of dew-point, corrected daily mean.	Date	Barometer, corrected daily mean.	Dry-bulb, corrected daily mean.	Depression of dew-point, corrected daily mean.
1856.	in.	°	°	1856.	in.	°	°
July 16.	21·930	61·8	31·2	Aug. 2.	21·919	58·2	28·7
17.	21·780	60·0	51·2	3.	21·865	55·9	29·8
18.	21·880			4.	21·884	55·5	16·3
19.	21·970	65·1	22·1	5.	21·914	56·8	32·1
20.	22·000	64·6	29·9	6.	21·979	56·4	25·6
21.	21·996	62·7	33·6	7.	21·972	58·4	31·3
22.	21·881	60·4	32·8	8.	21·921	59·3	47·4
23.	21·837	56·7	36·9	9.	21·867	57·1	44·4
24.	21·888	59·6	36·3	10.	21·898	57·0	44·4
25.	21·921	59·5	38·3	11.	21·928	59·9	40·4
26.	21·950	62·7	46·3	12.	21·956	65·0	30·1
27.	21·922	64·8	39·0	13.	21·984	63·7	29·3
28.	21·883	65·2	41·4	14.	22·011	62·3	25·0
29.	21·919	65·1	47·1	15.	22·004	60·2	29·2
30.	22·005	65·1	44·0	16.	21 993	62·4	31·5
Aug. 1.	21·959	58·9	34·3	17.	21·937	63·5	41·7

TABLE III.

Daily Means of Observations of Mountain Meteorological Journal at Alta Vista.

Date.	Barometer, corrected daily mean.	Dry-bulb, corrected daily mean.	Depression of dew-point, corrected daily mean.	Date.	Barometer, corrected daily mean.	Dry-bulb, corrected daily mean.	Depression of dew-point, corrected daily mean.
1856.	in.	°	°	1856.	in.	°	°
Aug. 21.	20·589	54·7	26·8	Sept. 8.	20·576	48·6	13·0
22.	20·613	56·7	22·1	9.	20·558	50·8	38·2
23.	20·564	58·5	30·9	10.	20·568		
24.	20·522	55·8	22·8	11.	20·493	48·1	34·2
Sept. 1.	20·372	44·8	35·3	12.	20·374	43·5	40·1
2.	20·452	45·3	26·1	13.	20·385	44·4	36·2
3.	20·468	46·1	24·5	14.	20·467	40·9	21·4
4.	20·485	49·7	29·2	15.	20·572	38·8	0·0
5.	20·508	51·8	27·4	16.	20·599	41·9	2·9
6.	20·553	50·9	16·9	17.	20·583	44·2	10·4

Variation of Daily Means.

Comparing all these determinations together for results, and beginning with the barometer, we find the variations at the sea-level to be somewhat greater than those on the mountain, and singularly inconsistent with them, except on one or two occasions, as the September storm at Alta Vista.

On the other hand, the variations of the thermometer are much greater on the mountain than at the sea-level, having amounted on Guajara to 9°·7 against 4°·5 at the sea-level, and on Alta Vista to 19°·7 against 6°·2 at the lower level for the same period.

The dew-point exhibits greater variations still, amounting on Guajara to 34°·9 against 9°·4 at the sea-level, and on Alta Vista to 40°·1 against 13°·6 at the lower level for the same period.

These variations of daily means exhibit inexplicable discordances, in no small measure on account of so small a portion of their cycle, viz. the year, being included in the observations; and before coming to the consideration of the absolute quantities for each day, it may be well to consider the monthly variations.

(3.) *Monthly Means.*

On taking the arithmetical means, the results indicated by the curves were powerfully confirmed, viz. that on the mountain, the maxima of temperature and dryness are earlier than below; summer, in fact, at a great height, is there nearly coincident with the solstice. Thus while at the sea-level the temperature went on increasing throughout July, August, and September, it was sensibly decreasing at Guajara in July and August; and at Alta Vista, in August and September, it was very rapidly falling. On going below the sea-level, or to the sea-water itself, the law was carried on further still, the numbers being as follows:—

Date.	Sea-level.			Sea-water, temperature of.	Guajara.			Alta Vista.		
	Barometer.	Temperature.	Depression of dew-point.		Barometer.	Temperature.	Depression of dew-point.	Barometer.	Temperature.	Depression of dew-point.
	inches.	°	°	°	inches.	°	°	inches.	°	°
1856, July	30·045	73·1	11·4	70·9	21·918	62·4	37·9			
August ...	30·036	73·8	11·3	72·8	21·941	59·6	33·0	20·572	56·4	25·6
September	30·083	74·9	11·4	74·2				20·500	46·0	23·7

These means represent the whole of the observations made in each month at the several stations; at the sea-level they include nearly the whole of each month, but on the mountain only about half a month each; this circumstance, however, will not touch the great fact now brought to light, of the mean temperature arriving at its maximum earlier at 10,702 feet than at 8903, and at 8903 earlier than below it.

Over and above this effect, the temperature appears to follow the law of decrease with altitude, but in an accelerating ratio so far as these *three* stations would indicate, which will be considered in the department of the "*peripatetic*" observations; and I would now rather advert to the most remarkable feature of all in the mountain climate, viz. the excessive dryness, amounting at Guajara, in the contrary terms of humidity (saturation=100), to 26, and at Alta Vista to 38, as the mean for two months, against 66 at the sea-level; or, in terms of grains of moisture in a cubic foot of air equally compressed in each case, to 1·5, 1·6, and 6·2.

Extreme Readings.

At the sea-level the highest maximum temperature daily mean was 78°·8 on Sep-

tember 16, and the lowest 71°·0 on July 17. At Guajara 65°·2 on July 28, and 55°·5 on August 4. At Alta Vista 58°·5 on August 23, and 38°·8 on September 15. Again, the greatest maximum mean daily depression of the dew-point at the sea-level was 19°·6 on August 27, and the minimum 6°·0 on August 29. At Guajara 51°·2 on July 17, and 16°·3 on August 4. At Alta Vista 40°·1 on September 12, and 0°·0 on September 15. To this we may add as examples of atmospheric dryness, that among the isolated observations on Guajara, the amount of depression of the dew-point was 58°·5 on July 17, the temperature being 51°·5; which gives only 0·4 grain of water in a cubic foot of air, and a humidity of no more than 10, while at the sea-level for the same instant it was 62.

(4.) *Winds.*

In the journals, at the sea-level and on the mountain, the velocity of the wind was entered in miles per hour by estimation. Guajara station, being quite on the top of the mountain there, and undominated by any neighbouring points, was favourable for getting the true direction of the wind. Alta Vista, on the contrary, being on the eastern slope of the Peak, was faulty as a site; and generally, by day, in normal weather, there was an east wind blowing up from the plain, and by night a west wind blowing down from the Peak.

Taking means rudely of the directions and strength of the wind as observed at each place, an approximate mean velocity and direction of the wind on each day has been obtained, and has been entered in Plate XXXVII. for the period to which it refers.

From these quantities, taking the mean of all the days of corresponding observations, we find that during thirty-four days at the sea-level, the mean velocity of the wind was 4·5 miles per hour, while on Guajara it was only 2·3 miles for the same time. On Alta Vista, again, the mean velocity during twenty-three days was 3·3 miles per hour, while it was 5·8 miles at the sea-level for the same period.

Between Guajara and the sea there is little change in the general direction of the wind, northerly being in both places to southerly as 2 to 1. On the Alta Vista, on the other hand, northerly directions were to southerly only as 1 to 10, the old proportion at the sea-level still remaining. Moreover, while at the sea-level about one-twentieth part of the whole wind was from the east, and none from the west, there was, with the same amount of east wind at Alta Vista, one-eighth of the whole from the west.

(5.) *Height of Stations.*

The great length of time during which simultaneous meteorological observations were kept up at either mountain station and on board the yacht, have afforded a good insight into the uncertainties still existing in the best barometrical formulæ for the determination of heights. The varying results from the means of successive days were very difficult to interpret; but when the hourly variations were tried, and found to exhibit a fluctuation through upwards of 170 feet at Guajara, and 280 feet at Alta Vista, the temperature of the upper station was clearly shown to be the agent at fault; and this

conclusion we have since ascertained to be remarkably borne out by the "peripatetic" observations on September the 8th. For, ascending the Peak on that day, and passing through a locality where there was a visible escape of volcanic steam, and a sensible increase of the temperature of the air, our observations show that a barometrical hump was thereby produced on the side of the mountain to the extent of 368 feet.

The formula employed was that of LA PLACE, as adapted to practice by FRANCIS BAILY in his Astronomical Tables.

Hourly Variation of Heights.

The following two Tables will show the manner of variation of the computed heights with change of the several meteorological conditions, one of the tables being also exhibited graphically in Plate XXXVI.

Guajara Station.

Date.	Hour.	Corrected barometer, at sea-level.	Thermometer.	Depression of dew-point.	Barometer, corrected on mountain.	Thermometer.	Depression of dew-point.	Altitude above sea-level.	Radiation at Guajara.
1856.		in.	°	°	in.	°	°	feet.	°
Aug 1.	4 A.M.	30·031	67·8						
	6 A.M.	30·052	69·7	6·3	21·955	57·5	37·3	8814·6	
	7 A.M.	30·046	70·0	5·6	21·952	58·6	36·8	8830·0	+ 52·4
	8 A.M.	30·043	71·8	7·8	21·975	60·0	39·2	8826·2	+ 66·7
	9 A.M.	30·055	72·6	8·7	21·992	61·9	39·9	8840·8	+ 77·4
	10 A.M.	30·061	71·5	7·3	22·000	64·0	38·6	8844·5	+ 82·8
	11 A.M.	30·053	71·7	7·9	21·998	66·3	41·5	8863·0	+ 82·7
	0 P.M.	30·044	74·0	10·2	21·995	66·7	40·4	8883·0	+101·6
	1 P.M.	30·032	75·8	12·0	21·975	66·4	42·2	8910·7	+ 85·8
	2 P.M.	30·023	75·1	10·4	21·978	66·5	41·5	8892·7	+ 82·3
	3 P.M.	30·019	73·8	9·2	21·966	66·7	41·3	8894·9	+ 74·9
	4 P.M.	29·995	73·8	9·2	21·960	65·5	40·5	8869·0	+ 73·0
	5 P.M.	29·991	74·3	10·0	21·946	62·4	38·8	8860·8	+ 62·4
	6 P.M.	29·996	74·8	10·0	21·958	60·5	35·7	8835·9	+ 62·0
	7 P.M.	30·003	72·6	8·2	21·961	58·4	35·4	8799·4	+ 2·5
	8 P.M.	30·015	71·0	5·7	21·968	57·3	36·9	8777·5	− 4·5
	9 P.M.	30·024	70·8	5·4	21·972	55·5	35·4	8762·6	− 4·2
	10 P.M.	30·031	70·3	4·6	21·966	55·9	32·1	8775·7	− 4·1
	11 P.M.	30·027	70·0	4·9	21·968	55·3	27·4	8761·0	− 4·3
	0 A.M.	30·018	69·8	4·6	21·956	54·3	27·9	8757·5	− 4·1
	1 A.M.	29·999	69·0	5·0	21·935	53·8	26·6	8753·1	− 3·8
	2 A.M.	29·994	68·3	4·0	21·931	53·9	26·1	8748·9	− 4·4
	3 A.M.	29·983	68·3	4·0	21·923	53·3	24·8	8744·2	− 3·9
	4 A.M.	29·986	67·8	3·9	21·919	52·6	23·0	8741·0	− 3·0
	5 A.M.	29·985	67·8	4·9	21·918	52·7	22·3	8742·0	− 2·4
	6 A.M.	30·008	68·3	4·9	21·918	53·5	23·6	8757·3	+ 26·8
							Mean.................	8843·45	

Alta Vista.

Date.	Hour.	At sea-level. Barometer, corrected.	Thermometer.	Depression of dew-point.	On mountain. Barometer, corrected.	Thermometer.	Depression of dew-point.	Altitude above sea-level.
1856.		in.	°	°	in.	°	°	feet.
Aug. 21.	4 A.M.	30·054	71·8					
	6 A.M.	30·095	71·8	7·8	20·541	48·7	18·5	10653·9
	7 A.M.	30·103	73·3	9·3	......	......	21·0	
	8 A.M.	30·108	73·8	10·0	20·577	54·4	24·2	10702·7
	9 A.M.	30·132	74·4	9·8	20·594	58·9	31·4	10758·5
	10 A.M.	30·134	75·6	10·4	20·590	62·6	36·8	10820·4
	11 A.M.	30·132	77·1	11·1	20·592	66·0	37·2	10869·1
	0 P.M.	30·109	77·1	11·1	20·589	65·2	41·0	10843·6
	1 P.M.	30·099	76·3	10·1	20·587	65·5	39·1	10831·6
	2 P.M.	30·101	76·0	11·3	20·588	63·4	36·4	10805·2
	3 P.M.	30·092	74·8	10·0	20·591	61·4	34·6	10757·0
	4 P.M.	30·089	75·8	13·2	20·602	58·4	29·6	10717·2
	5 P.M.	30·114	74·6	10·8	20·607	56·3	26·5	10697·5
	6 P.M.	30·125	74·3	10·3	20·610	54·7	23·1	10682·5
	7 P.M.	30·139	73·8	11·0	20·613	53·3	21·7	10670·7
	8 P.M.	30·155	73·6	9·8	20·621	52·3	22·4	10661·4
	9 P.M.	30·167	73·8	9·9	20·619	51·2	19·8	10665·0
	10 P.M.	30·173	73·8	9·6	20·618	51·8	18·8	10678·8
	11 P.M.	30·158	73·6	10·6	20·614	48·8	19·1	10634·6
	0 A.M.	......	......	9·9				
	1 A.M.	30·130	73·0	8·8	20·595	48·4	19·2	10623·6
	2 A.M.							
	3 A.M.							
	4 A.M.	30·104	72·1	8·2	20·591	49·1	21·1	10602·1
	5 A.M.	30·105	71·6	8·5	20·595	48·6	19·2	10587·2
	6 A.M.	30·125	71·8	8·8	20·598	49·3	19·1	10586·0
						Mean..................		10707·08

Daily Variations of Heights.

From the daily means already given for each of the three stations, the computed height of Guajara varies thus:—

Date.	Feet.	Date.	Feet.	Date.	Feet.	Date.	Feet.
July 21.	8793·3	July 28.	8950·4	Aug. 5.	8961·7	Aug. 12.	8899·8
22.	8913·6	29.	8868·3	6.	8897·0	13.	8848·8
23.	8988·0	30.	8810·3	7.	8916·0	14.	8807·9
24.	9005·6	Aug. 1.	8821·3	8.	8931·8	15.	8776·3
25.	8993·6	2.	8845·9	9.	8942·4	16.	8822·1
26.	8974·5	3.	8930·0	10.	8902·9	17.	8913·0
27.	8966·5	4.	8982·6	11.	8917·7		

and that of Alta Vista as follows:—

Date.	Feet.	Date.	Feet.	Date.	Feet.	Date.	Feet.
Aug. 21.	10,688	Sept. 2.	10,715	Sept. 8.	10,666	Sept. 14.	10,674
22.	10,691	3.	10,731	9.	10,656	15.	10,597
23.	10,687	4.	10,768	11.	10,708	16.	10,617
24.	10,689	5.	10,754	12.	10,747	17.	10,562
Sept. 1.	10,704	6.	10,720	13.	10,758		

For the height of Guajara, the mean of its series, or 8903 feet, may be adopted.

For the height of Alta Vista, the mean of the whole series is 10,691 feet; but seeing that decidedly exceptional weather began on September 14, and that the mean of the days from August 21 to September 13 is 10712, the mean of the two determinations may probably be the closest approximation to the real height, which therefore comes out 10,702 feet.

(5*.) *Difference of Meteorological Elements between the Yacht in Santa Cruz Roads and the Town of Orotava.*

The mountain observations having been necessarily compared with the series of Captain CORKE on board the 'Titania,' and that vessel lying all the time in Santa Cruz Roads, at the eastern end of Teneriffe and on the southern coast, while the Peak is rather towards the western end and on the northern coast;—it became desirable to ascertain whether any, and what constant differences might occur between that station of the yacht, 30 miles N. 60° E. of the Peak, and the town of Orotava, which lies only at a distance of 12 miles and in the direction N. 30° E.

Facilities for this purpose were afforded by Mr. FRANZ KREITZ, a skilful German watch-maker, formerly of Hamburg, who zealously undertook to observe some of the instruments kindly lent by Admiral FITZROY on the part of the Board of Trade.

Having established these instruments under good circumstances of exposure at M. KREITZ's, on August 29, I left him with instructions for observing them simultaneously to the ordinary Yacht times of observation; and on September 24 he furnished me with a series of readings of the barometer and dry- and wet-bulb thermometers, taken three times a day, or oftener, for the whole of the intervening period. These observations having been duly corrected for index errors, and reduced in a manner similar to the Yacht observations, are found, on the mean of each day, to give the following series of corrections to reduce the Orotava series to the Santa Cruz:—

Date.	Barometer.	Temperature.	Depression of dew-point.	Date.	Barometer.	Temperature.	Depression of dew-point.
1856.	inches.	°	°	1856.	inches.	°	°
August 30.	+·055	−0·1	−0·7	September 11.	+·063	+0·1	+ 2·9
31.	·134	+0·6	−0·2	12.	·082	−0·8	− 0·8
September 1.	·064	−2·4	−0·4	13.	·107	−3·0	− 3·8
2.	·058	−1·7	+1·7	15.	·043	+2·1	+ 5·0
3.	·061	−1·9	+0·4	16.	·015	+4·0	+ 9·2
4.	·067	−0·9	+3·8	17.	·036	+4·3	+11·8
5.	·063	−0·4	+3·3	18.	·062	+2·0	+ 7·3
6.	·047	−1·6	+1·2	19.	·074	+1·2	+ 2·9
7.	·078	−1·7	−0·4	20.	·090	+2·4	+ 7·8
8.	·076	−2·0	+0·4	21.	·063	−0·9	+ 1·6
9.	·051	−1·6	+1·9	22.	·083	−1·0	+ 1·2
10.	+·053	−0·8	−0·1	23.	+·099	+1·0	+ 1·8

The mean barometrical difference appears to answer very closely to the elevation of M. KREITZ's house above the level of the sea, or about 80 feet, the temperature of which

appears in average weather to have been 1°·1 greater, and the depression of the dew-point 1° less than on board the yacht. Exceptional weather occurred from September 13 to September 20, and appears to have been in connexion with the Alta Vista storm of the 14th, though not in exact coincidence. As this was a period during which the computed barometric altitudes of the mountain station gave very wild results compared with the yacht, we have computed the upper observations again as compared with Orotava; but the discordances are even greater, as the enclosed numbers will show, and they are evidently in connexion with the same general disturbances of the atmosphere, thereby reflecting credit on both the lower observers.

Date.	Height of Alta Vista above Orotava.	Correction to mean.	Height of Alta Vista above yacht.	Correction to mean.
	feet.	feet.	feet.	feet.
1856, Sept. 1.	10,672	− 30	10,704	− 10
2.	10,680	− 38	10,715	− 21
3.	10,695	− 53	10,731	− 37
4.	10,715	− 73	10,768	− 74
5.	10,699	− 57	10,754	− 60
6.	10,695	− 53	10,726	− 32
8.	10,618	+ 24	10,666	+ 28
9.	10,627	+ 15	10,656	+ 38
11.	10,646	− 4	10,708	− 14
12.	10,680	− 38	10,747	− 53
13.	10,692	− 50	10,758	− 64
15.	10,534	+108	10,597	+ 97
16.	10,559	+ 83	10,617	+ 77
17.	10,482	+160	10,562	+132

Boiling-point Thermometer.

A boiling-point thermometer, made by Mr. Adie of Edinburgh, graduated to tenths, and reading to hundredths of a degree, and since admirably tested by my friend Mr. Welsh of the Kew Observatory, was observed with at Guajara, Alta Vista and the Peak, but not so often as I see would have been desirable; so that I can only now state that for approximative purposes Captain Boileau's Tables are most satisfactory, giving by two observations the height of Guajara subject to a correction of +40 feet, Alta Vista +70, and the Peak −26; the corrections of simultaneous barometrical altitudes being +122, +98, and −2 feet.

(6.) *Peripatetic Observations.*

In all the journeyings up and down the mountain, the altitudes were measured by myself with a sympiesometer, especially made for the occasion by Mr. John Adie. From the simultaneous readings of this instrument with the barometer at Orotava, Guajara, and Alta Vista, a temperature and an altitude correction have been made out, and have been applied in every case to reduce the sympiesometer reading to what our barometer, corrected, would have shown at the same place and time. The calculation of the height was then performed as with a barometer reading. The height so found

was corrected further for the variation of barometric height with the hour of the day, as indicated by the observations already given, and arranged in the following approximate Table, where the sign shows the manner in which the tabular feet are to be applied as *corrections* to the barometrical, to give the true altitude; the arguments along the top of the Table being the approximate height of the station, and on the side, the hour of the day, apparent solar time.

Correction for Barometrical Altitudes for hour of day, and approximate height.					
	Approximate altitude of station in feet.				
Approximate solar time of observation.	10,000.	8000.	6000.	4000.	2000.
h					
6 A.M.	+ 15	+12	+ 8	+ 5	+ 2
7 A.M.	+ 5	+ 4	+ 2	+ 2	+ 1
8 A.M.	0	0	0	0	0
9 A.M.	− 20	−15	−10	− 6	− 3
10 A.M.	− 70	−52	−35	−23	−12
11 A.M.	−100	−75	−50	−33	−17
0 P.M.	−100	−75	−50	−33	−17
1 P.M.	−115	−80	−60	−40	−20
2 P.M.	− 95	−72	−50	−33	−17
3 P.M.	− 60	−45	−30	−20	−10
4 P.M.	− 30	−22	−15	−10	− 5
5 P.M.	− 10	− 8	− 5	− 4	− 2
6 P.M.	− 5	− 4	− 2	− 2	− 1

For the height of the Peak, measured during an ascent on September 8, and resting on five hourly observations from 11 A.M. to 4 P.M., a special method was employed. The barometer was simultaneously observed at Alta Vista, and gave the height of that station, for the interval, too high by 35 feet, this quantity being compounded of the daily and the hourly correction. Then increasing this quantity to 41 feet, for the proportion between the height of the Alta Vista and the sympiesometer station in a cleft on the western side of the crater at the summit of the Peak, and levelling thence to the culminating point of the whole, a part of the north-eastern wall of the crater, we have 12,198 for the height of the Peak of Teneriffe.

A series of heights of notable points will then run as follows:—

		Engl. feet.
Cone of eruption.	Culminating point of the Peak	12,198
	Base of small cone on the eastern side, or Rambleta	11,745
	Narix	11,600(?)
	Ice cavern	11,044
	Alta Vista	10,702
	Estancia de los Ingleses	9,710
	Base of steepest portion of great cone of eruption, where it adjoins Montana Blanco	8,930

	Engl. feet.
Guajara, or culminating point of wall of great crater of elevation .	8,903
Floor of crater of elevation, generally	7,200
Cañadas, or outer boundary of the floor	6,900

From this last level there is a nearly uniform descent on the Orotava side, at an angle of about 12 degrees to the sea beach.

The height of the Narix entered above, is derived from the sympiesometer observations made half an hour before reaching, and three-quarters of an hour after having passed it, on our slow ascent of the Peak on September 8. The instruments were observed also at the Narix, *i. e.* within about ten yards of the little vent-hole, out of which about as much steam was issuing as a 2-inch pipe might supply from a low-pressure boiler. As far as I knew at the time, the Narix observations were equal in value to any that were made that day, and were accordingly computed with the rest; they gave a height of 11,868 feet, or upwards of 100 feet higher than the next observation-point which we reached in our continual ascent of the regular slope of the mountain. A difference of 10 degrees in the temperature at the Narix and the other stations looked at first like an error of observation; but on referring to the original note-book, and finding that the increase was not an exact ten, and had been participated in by the thermometer of the sympiesometer, the dry-bulb and the wet-bulb, there could be no doubt of the observations being good, and fully trustworthy in as far as lay in them.

The instruments then may be considered to show that there is an escape of volcanic heat at this point; and seeing that the depression of the dew-point is somewhat increased also, we may look on the steam as a consequence rather than the cause of this local warmth. Reducing the temperature above and below the Narix to the mean for 24 hours, and taking the mean of them, 46°·7 is given as the true temperature of the level of that spot, the observed, after similar correction, being 57°·5. Similarly with the depression of the dew-point, 28°·7 ought to have been found, but the instrument showed 32°·2.

(7.) *Meteorological Descent and Ascent of the Mountain.*

In descending from Alta Vista to Orotava on August 25, and ascending again on August 30 with the large equatorial, I took the opportunity of making careful meteorological observations, placing the instruments we had used on the mountain in a sort of portable observatory, or tall box, fastened on a mule in such a position as to hang nearly vertical; and, while made with numerous openings above and below and on the sides, to admit of the circulation of air, it was covered outside with bright tinfoil, to guard against effects of solar radiation. The mule was stopped whenever observations were to be made, or the wet-bulb to be wetted; and the results are as worthy of confidence as those made at one of the stationary positions. They were, however, necessarily loaded with the hourly variations, and to eliminate these, tables of double entry have been constructed to reduce the thermometer and depression of dew-point, observed at any instant, to the

mean for 24 hours, at all levels from 0 to 11,000 feet; the materials for the construction of the Table being afforded by the results already given for Alta Vista, Guajara, and the yacht at Santa Cruz. These corrections having been applied, we have in the resulting quantities only the effect of height, wind, and such local circumstances as would affect also instantaneous ascents and descents of the mountain, were such possible.

The quantities are thus for August 25:—

Height in feet.	Temperature reduced to mean of twenty-four hours.	Dew-point depression reduced to mean of twenty-four hours.	Humidity, saturation =100.	Wind.		Clouds.	
				Velocity.	Direction.	Upper.	Lower.
				miles per hour.			
10,710	64°·5	29°·1	37	1	S.E.	0	Dense.
9,769	63·6	31·4	34	2	W.	—	—
8,870	63·9	30·6	36	3	W.	—	—
8,375	65·8	36·6	29	6	W.	—	—
8,236	67·9	41·4	24	3	S.W.	—	0
7,436	70·6	35·5	32	1	S.W.	—	—
7,186	71·8	38·9	27	0	...	—	—
6,936	72·5	33·2	33	—	—	—	—
6,758	73·1	33·0	33	—	—	—	—
6,702	73·5	31·9	35	2	N.	—	—
6,069	75·0	29·4	38	2	N.	—	—
5,470	75·8	32·7	34	1	N.	0	Dense.
5,025	76·6	31·7	35	2	N.	—	—
5,448	81·4	20·1	52	...	...	—	—
3,379	85·3	18·6	55	0	...	—	0
2,460	81·3	17·7	57	2	N.	...	
1,948	75·8	12·9	66	3	N.	7 ∩	
1,651	75·0	12·8	66	2	N.E.	8 ∩	
1,000	73·6	9·9	72	0		8 ∩	
803	74·0	10·7	70	0		8 ∩	
548	74·1	11·4	69	2	N.E.	3 ∩	
324	74·3	10·5	71	1	N.E.	2 ∩	
5	74·7	10·6	71	0	...	3 ∩	
24	75·7	11·0	70	0	—	0	0

And thus for August 30:—

Height in feet.	Temperature reduced to mean of twenty-four hours.	Dew-point depression reduced to mean of twenty-four hours.	Humidity, saturation =100.	Wind.		Clouds.	
				Velocity.	Direction.	Upper.	Lower.
				miles per hour.			
13	76°·8	6°·8	80	0	...	10 ∩	
304	75·6	6·6	81	—	...	—	
839	74·1	6·6	81				
1,435	73·2	6·1	82				
1,837	72·7	5·8	83	—	...	—	
2,292	73·0	5·6	83	0	...	5 ∩	Near level of cloud, but it is dispersing.
3,460	74·1	6·9	80	0	...	2 ∩ ⊙ hot	Dense to sea-ward.
3,696	75·4	6·3	82	...	...	3 ∩	
4,157	76·7	14·4	62	0	...	5 ∩	Dense.
4,769	75·7	10·5	71	1	N.W.	7 ∩	—
5,160	73·9	20·5	51	1	N.W.	7 ∩	—
5,904	71·9	26·4	41	0	...	7 ∩	—
6,521	70·2	24·4	44	1	N.	7 ∩	—
6,875	69·0	25·3	43	1	N.	5 ∩	—
7,234	64·9	23·3	46	3	N.	5 ∩	—
7,792	67·9	25·3	43	3	S.W.	5 ∩	—
8,260	65·2	21·8	48	4	S.	5 ∩	—
8,976	60·5	19·7	51	3	S.W.	5 ∩	—
9,662	52·8	13·0	64	1	S.W.	3 ∩_\\	—
10,710	47·4	7·2	78	2	S.W.	3 \\ and ∩ Cloud on Peak or close above station.	—

These quantities are likewise exhibited in the Plates XXXVIII. and XXXIX.

The first result deducible from the two preceding Tables, is the remarkable confirmation which they give, of Mr. Welsh's discovery in his balloon ascents, of a break in, or a very great anomalous deviation from, the law of decrease of heat with the elevation, at a height of a few thousand feet above the sea. The reason of this anomaly seems to be indicated at the same time; for it occurs not at any passage from one wind to another, not at any break in the slope of the mountain, but at the level of the cloud stratum. This is the only noteworthy circumstance that can be found accompanying the deviation from the law, and may arise partly from the reflexion of heat by the brilliant upper surface of the cloud, and partly, as suggested by Mr. Welsh, in connexion with the conversion of latent into sensible heat, dependent on the condensation of vapour into cloud. In either case, the practical result is the same; viz. that at any moderate height above the clouds, the temperature of the air is by no means so low as might have been computed from the usual hypsometric idea of gradation.

The second result is, further confirmation to Green's and Sabine's, of Daniell's conclusion of dryness above the cloud stratum. From the sea-level to the clouds, 3000 feet high, the depression of the dew-point is small, but immediately after passing that height

the depression increases from 10° to 30°. On August 25, however, a rapid diminution is indicated at about 10,000 feet, and the concomitant circumstance is observed, that there is that day a cloud on the top of the Peak (12,000 feet high); and as in ascending we gradually came underneath the mist, we were evidently approximating to the conditions of our starting from the sea-level, with the 3000-foot stratum of cloud above us.

A third result we may draw is, that while the expected difference was found between the wind at the top and bottom of the mountain, viz. S.W. above and N.E. below, the stratum of cloud was not found in the space between the two, but in or below the middle of the N.E. current of air. This was certainly only the mountain cloud, which is limited in horizontal extent to a few miles; but even the sea- or the true N.E.-cloud, which was far more extensive,—stretching, in fact, as far as the eye could observe, when many thousand feet above it,—only reached to between 4000 and 5000 feet of elevation, while the N.E. wind extended in height from the very sea itself to about 9000 feet. This was the general state of things for over two months at Guajara, when the weather was settled in its N.E. trade; and it may be perhaps only when a storm comes to break up the adjustment, that a cloud finds itself occasionally, as may be seen about Table Mountain in South Africa, between two opposite currents of air, and made to spin round and round by their opposing action.

(8.) *Electricity.*

For upwards of a month, an electrometer (lent by Mr. Airy) was observed daily on Guajara. The instrument had travelled so safely, that the two strips of gold-leaf that had been attached in England, were found in good working order in Teneriffe. The glass bell, however, having unfortunately been fixed by the maker in a wooden base, the contraction of this from excessive drought at last broke the bell. During the whole period of observation by day and by night, the electricity was moderate in quantity, and always resinous; this was during the season of the N.E. trade-wind, and within its influence, though above its clouds. Had the instrument lasted longer, something more varied, if not more interesting, would have been found; for our subsequent experiences at Alta Vista introduced us to a different current of the atmosphere, and at last to a complete change of weather; and on the very day that we left, September 19, a heavy shower of rain fell, accompanied with a cloud on the Peak, two or three flashes of lightning, and somewhat loud thunder. This was the first electric display we had seen since entering the region of the trade-winds on July 5, in lat. 37°, and it certainly came from the S.W. Occasionally I had thought at Guajara that there were indications of electricity in the forms of the clouds floating at a great height over the station from the S.W.; and on the night of August 1st and the morning of August 2nd (see Meteorological Journal), I watched with intense interest a large cloud that remained stationary over the mountain for seven hours, and was every moment altering its form, fitfully and instantaneously, more like an aurora than a cloud. On no occasion, however, was the electrometer affected; and on no occasion, indeed, did we cease to be under the domina-

tion of the lower polar current. At the sea-level there was a similar absence of electricity during the summer; but I have since been informed by a letter from my friend Mr. HAMILTON of Santa Cruz, that when the autumn set in there below in November, as it had done above in September, it brought S.W. wind, rain, and snow with it, and so much electricity, that a house in Orotava was destroyed by lightning.

(9.) *Alta Vista Storm of September 14th.*

From August 30th a decided change from the long-continued routine of the summer weather took place; a cirrous cloud formed on the Peak that day, immediately above our heads at Alta Vista; and the appearance of the fibres of misty cirri dissolving, reforming, and driving over the mountain top, was dazzlingly beautiful. I have had abundant experience of ordinary clouds on mountain tops, under 6000 feet in height; but they were always dull foggy mist, in fact NEWTON'S "grosser clouds;" and I can therefore speak positively to this "cirrous" cloud on the Peak being something unusual in its nature and mode of composition. A strong S.W. wind blew subsequently for three days; and though the weather settled again, we could not but be struck with the change that had occurred in the N.E. cloud. Still it formed its usual stratum at about 4000 to 5000 feet high, but its long rolls of cumuloni were broken up into separate and distinct cumuli; and on the south side of both Teneriffe and Grand Canary we could see similar bodies of clouds advancing from the S.W., climbing the steep sides of the island, and contesting the possession of the ridges day after day with the N.E. clouds. This remarkable aërial combat was carried on under our eyes with various success until September 11th, when the S.W. cloud obtained a preponderance, with a sinking barometer. The next day the S.W. cloud was decidedly the victor, while the N.E. cloud, simply to describe the actual facts, was retiring before it in broken and disorganized masses. The following day the barometer rose from 20·363 to 20·410, and the succeeding morning, the 14th, to 20·473; at this time, however, were perceived on the sea, between Teneriffe and Grand Canary, extraordinary appearances of some unusual and grand current from the S.W., for there were long curved lines traceable for fifty or more miles in their length, indicating a stream setting in between Teneriffe and Canary. The sky soon after became cloudy above our heads; at 1 P.M. a sudden and heavy shower of rain and hail came down; at 5 P.M. the cloud descended upon Alta Vista; and at 7 P.M. heavy rain began with a violent wind from the S., producing more than 2 inches of rain in a gauge before the next morning.

During this period the barometer remained almost stationary, the temperature was lowered five or six degrees; but the remarkable change was in the dew-point. At 9 A.M., on the 14th, the amount of depression was 46°·1; at 3 P.M. it was 22°·5; at 5 P.M. 2°·5; and at 10 P.M. as low as 0°·8.

On the 15th the depression was as low as 0°·5, but the active part of the storm had passed; the wind, which had been estimated during the previous night at a velocity of fifteen miles per hour, lowered to seven and to five, the cloud elevated itself so as just

to clear Alta Vista by about 300 feet, and at 8 P.M. the depression of the dew-point was 1°·1.

On the 16th the barometer had risen to 20·632, the temperature increased from 39°, its lowest, to 43°; and the depression of the dew-point to 5°·3.

During these days, and until the 19th, when we left the mountain, the sky was continually cloudy, *i. e.* there was a stratum of cloud at a height greater than 12,000 feet, in addition to the lower stratum at 4000 feet, and this upper bed was eminently hazy and misty. The sun by day, and the moon by night, were seen as pale and watery as they are in the generality of English weather; the autumn had in fact set in on the mountain top, and that locality had lost its specialities as a site for astronomical observations.

On descending the mountain, beyond the N.E. cloud being broken up and scattered, we found that no perceptible change in the weather had been experienced below. On the night of the 14th, when we on the mountain were fearing that the station at Alta Vista would be undermined or be washed away by the torrents of rain, not a drop had fallen on either the N. or S. coast of the island; nay, even a party of visitors who had left us at about 3 P.M. on that day, after the hail-storm, gained the bottom of the mountain without any more wet; and on referring to the Captain's journal on board the yacht, some of the warmest weather of the whole season occurred with him, when we were at the wettest and coldest on the mountain.

The storm then, which, with all its accompaniments, we are justified, by the continual degradation of temperature going on during the whole period of our tenure of Alta Vista, in considering as the commencement of autumn, was confined to the upper regions of the atmosphere and the mountain top, not descending probably below 9000 feet of elevation. This circumstance in itself, viewed as part of a general law, will cause a different rate of decrease of the heat of the atmosphere with altitude, at different seasons of the year; for, in September for instance, we should be stepping from summer below to autumn above; and the actual difference found, will be further increased, if there be an upper stratum of cloud to reflect back the heat of the sun, in the same manner as the lower stratum was found to do in our meteorological journeys. There was, too, such an upper stratum on September 14th and following days; and it appeared also to produce the lowering of the temperature above described, as well as the lessening of the depression of the dew-point. As all these matters are so intimately connected with the theory of refractions and of barometrical altitudes, I subjoin a list of daily differences of mean temperature at the sea-level, and at the height of 10,702 feet as observed:—

August 21	18°·9	September 8	24°·5
August 22	16·7	September 9	22·3
August 23	14·1	September 11	25·3
August 24	17·0	September 12	30·1
September 1	29·2	September 13	29·2
September 2	29·5	September 14	32·5
September 3	27·5	September 15	39·6
September 4	24·6	September 16	36·9
September 5	22·2	September 17	34·1
September 6	23·9		

[Section added during the printing.]

(10.) *Epoch of maximum Summer Heat.*

Most intimately connected with the results just given, must be the epoch of maximum annual heat at the surface of the ground; and attention was called in 1820 by the learned Leopold von Buch, to a very remarkable anomaly in the annual march of temperature for Las Palmas, the capital of Grand Canary; in accordance with which the greatest heat was experienced there in the month of October; and this result seemed all the more noteworthy, as a series of observations at Santa Cruz, in Teneriffe, showed, he thought, no deviation of a similar kind.

On comparing, however, the numbers given by him with the more numerous results since ascertained for other parts of the world, it appeared to us that the Santa Cruz epoch of greatest heat, though earlier than that of Las Palmas, is yet sensibly behind the normal period. The question therefore was then raised,—Does the anomaly still exist, and to what amount? Our own observations extend over too short an interval to settle the point; but some of the instruments which we left behind in Orotava, furnished to us in the first instance by the liberality of Admiral Fitzroy, have since been used with so much intelligence, and observed with daily for a period of thirteen months, by Herr Kreitz, watch-maker of that city, that they have afforded valuable data for the purpose; and the results of his 9 A.M. observations alone are exhibited in the following Table, together with those on which Von Buch depends, viz. 10 years' observations ending, it is believed, in 1816, in Las Palmas, Grand Canary, by Dr. Bandini de Gatti, and 2½ years of observations in Santa Cruz de Teneriffe, by Don Francisco Escolar in 1808, 1809, and 1810. These are reduced, for facility of comparison, to Fahrenheit's scale; not so much, be it remembered, for contrasting their absolute temperatures, which would include instrumental corrections that are unknown, in addition to secular changes, as for the sake of their differences from month to month, which are free from those manifest sources of error.

Months.	Days.	Las Palmas, Grand Canary. Mean of ten days, Reaum.	Las Palmas, Grand Canary. Mean of ten days, Fahr.	Las Palmas, Grand Canary. Mean of month, Fahr.	Puerto de Orotava. Mean of ten days, Fahr. 1856.	Puerto de Orotava. Mean of ten days, Fahr. 1857.	Puerto de Orotava. Mean of month, Fahr.	Santa Cruz de Teneriffe. Mean of ten days, Reaum.	Santa Cruz de Teneriffe. Mean of ten days, Fahr.	Santa Cruz de Teneriffe. Mean of month, Fahr.
	1 to 10	13°·42	62°·19	°	°	61°·56	°	14°·24	64°·04	°
Jan.	11 to 20	13·40	62·15	61·99	....	61·68	61·06	14·09	63·70	64·11
	21 to 31	13·17	61·63		....	59·94		14·48	64·58	
	1 to 10	14·02	63·54		....	59·59		13·60	62·60	
Feb.	11 to 20	14·01	63·52	63·71	....	60·43	60·51	14·16	63·86	63·70
	21 to 28	14·25	64·06		....	61·51		14·51	64·65	
	1 to 10	14·42	64·44		....	61·08		15·41	66·67	
March	11 to 20	14·46	64·54	64·75	....	62·95	62·95	15·54	66·96	66·79
	21 to 31	14·79	65·28		....	64·83		15·44	66·74	
	1 to 10	15·14	66·06		....	68·38		15·59	67·08	
April	11 to 20	15·32	66·47	66·31	....	67·30	67·69	15·88	67·73	67·43
	21 to 30	15·29	66·40		....	67·38		15·77	67·48	
	1 to 10	15·80	67·55		....	70·69		16·69	69·55	
May	11 to 20	16·20	68·45	68·23	....	70·22	70·62	17·81	72·07	71·85
	21 to 31	16·30	68·68		....	70·94		18·64	73·94	
	1 to 10	16·53	69·19		....	73·00		18·28	73·13	
June	11 to 20	16·95	70·14	69·99	....	73·44	74·33	18·52	73·67	73·89
	21 to 30	17·17	70·63		....	76·54		19·05	74·86	
	1 to 10	17·98	72·46		....	75·47		19·62	76·14	
July	11 to 20	18·71	74·10	73·63	....	76·48	76·65	20·18	77·40	77·20
	21 to 31	18·82	74·34		....	78·01		20·47	78·06	
	1 to 10	19·43	75·72		....	76·35		20·94	79·12	
Aug.	11 to 20	19·65	76·21	76·21	....	76·26	76·44	21·03	79·32	78·67
	21 to 31	19·87	76·71		75·63	77·82		20·25	77·56	
	1 to 10	20·95	79·14		77·56	79·14		20·52	78·17	
Sept.	11 to 20	21·58	80·56	80·69	76·18	77·72	76·76	19·96	76·91	77·38
	21 to 30	22·38	82·36		75·71	74·24		20·03	77·07	
	1 to 10	23·42	84·70		74·02	....		19·72	76·37	
Oct.	11 to 20	23·54	84·96	84·12	73·03	....	74·15	19·02	74·80	74·65
	21 to 31	22·53	82·69		75·41	....		18·13	72·79	
	1 to 10	19·98	76·96		73·13	....		18·05	72·61	
Nov.	11 to 20	17·32	70·97	71·96	68·41	....	68·61	17·08	70·43	70·42
	21 to 30	15·98	67·96		64·30	....		16·10	68·22	
	1 to 10	14·42	64·44		69·84	....		15·99	67·98	
Dec.	11 to 20	13·72	62·87	63·33	66·19	....	66·09	15·37	66·58	66·21
	21 to 31	13·64	62·69		62·25	....		14·26	64·08	
	Mean of year			70·41			69·65			71·02

From this Table then we may gather, that while the epochs of *minimum* temperature for the three places are nearly normal, viz. January 20, February 5, and February 1, the times of *maximum* are October 12, September 5, and August 18; all of them too late, and Las Palmas most notably so. Their *mean* temperatures, however, do not differ much, and Las Palmas, it is worthy of remark, is not the highest of them; but their differences of semi-annual extremes, or 22°·13, 16°·25, and 14°·97, are extremely discordant, and increase continually with an expressive "continental" character, so to speak, or in remarkable accordance with the actual retardation of their summer waves of heat; a circumstance which would have been exactly reversed, if the drag had resulted from the presence of proportionate depths of badly conducting matter, as with earth-thermometers.

The case is therefore altogether most deserving of further inquiry, which, to be successful, must be prefaced by more observations, not only at many different points in the Canarian Archipelago, but at several levels in the atmosphere; for on the different superimposed currents of air, and their respective strata of cloud, it is very evident that a large part of the anomalies of terrestrial-surface climate most intimately depend.

(11.) *Tidal Observations.*

The exposed condition of the Santa Cruz beach offered more difficulties to carrying on tide observations than had been expected, or than I should have been able to overcome, but for the warm cooperation of Mr. Lewis Hamilton, and more particularly of Don Francisco Aguilar, the Engineer of the Mole, who being engaged on some repairs of that structure, kindly undertook the building of such a vertical trough as should be secure from the severe swell usually prevailing. This tide-gauge was only completed on the day of my leaving Santa Cruz: and I could do little more than admire the regularity of the rise of the rod, though the tide came in with great rollers; test the divisions engraved on it, which proved to be English feet and inches; and arrange for the making of some observations, which the Don most obligingly offered to superintend.

The first point to be inquired into was the probable existence of any hitherto unrecognized anomaly in the tide-wave. To detect any such feature, Don Francisco Aguilar kept up observations at five-minute intervals, from 5 o'clock in the morning of the 13th to 9 o'clock in the evening of the 16th of October, 1856.

On projecting these numerous and, I believe, most carefully registered measures, the tide-wave appeared most satisfactorily single; and on communicating them to Dr. Whewell, he expressed himself perfectly content with their freedom from any feature requiring observations at other instants than about the times of high and low water in the ordinary manner.

Matters were thus far cleared and made ready for the next investigation; but before the requisite instructions could reach Santa Cruz, the alterations of the Mole had reached the part where the tide-gauge stood, and compelled its removal. The authorities were again very obliging in giving their permission to the machine's re-erection at a different spot; but this I was not able to undertake.

The Don's observations, already alluded to, are contained in full in volume 1, and give the following times and heights of low and high water:—

Date.	Time. Mean time, Santa Cruz.	Low-water depth.	High-water height.	Moon's meridian transit, South and North.	Luni-tidal interval.
1856.	h m	ft. inches.	ft. inches.	h m	m
October 12.	17 27	3 6·12?			
	23 42	......	4 5·00	23 23	−19
13.	5 52	3 11·75			
	12 3	......	3 10·75	11 49	−14
	18 3	3 10·25			
14.	0 23	......	4 6·25	0 16	− 7
	6 28	3 11·00			
	12 46	......	3 11·75	12 43	− 3
	18 51	3 9·50			
15.	1 9	......	4 3·75	1 11	+ 2
	7 14	3 7·00			
	13 34	......	3 8·87	13 40	+ 6
	19 30	3 7·50			
16.	1 45	......	3 8·00	2 10	+25
	8 0	3 2·87			

Projections of the above tides indicate 8 feet 3·25 inches as the amount, and thirteen days twenty-two hours as the epoch of extreme rise and fall, or $12^h\ 4^m$ after the instant of full moon. The minutes thus given, and to some extent the hours also, must be taken only as an accidental result of the numbers employed, but come curiously close to the intervals between the times of high water and the moon's transits as given in the last column of the above Table, where the mean of the whole comes to 1 minute, or with 12 hours added, to $12^h\ 1^m$.

These numbers, on being compared with the only published statement I have been able to meet with of the tide at Teneriffe, appear, by their difference therefrom, to justify some further inquiry into them for scientific purposes, at the same time that their differences *inter se*, at first looking anomalous, but soon proving to be correct, as shown particularly in the semidiurnal differences of the high waters, indicate the accuracy of Don Francisco Aguilar's observations.

A barometer, kindly lent by Admiral Fitzroy, was observed by Mr. Hamilton of Santa Cruz during the above observations, and within half a mile of the place where they were made. The differences were so small, that no attempt has been made to correct the height of the tide for them. At 3 P.M. and 9 P.M., the maximum and minimum nearly of the atmospheric wave, the readings were thus:—

	3 P.M.	9 P.M.
	inches.	inches.
October 13.	30·21	30·23
14.	30·20	30·23
15.	30·22	30·23
16.	30·20	30·23

CHAPTER VI.

GEOLOGY.

(1.) *General Topography.*

For the coast line of Teneriffe, the larger Admiralty Map of 1838, by Captain VIDAL, appears to be the best, as well as most original, authority, and is much esteemed in the island. For the interior, a safer guide is presented by Von BUCH's large and well-known map—a magnificent specimen of line engraving, and a most elaborate example of conventional hill-shading, carried out to its ultimate consequences. As a survey by a single individual, during part of one summer, it must be viewed as a prodigy of performance; while the profound geological knowledge of its author has successfully interpreted many volcanic features, which have been rather lost sight of in other maps. Yet he has also some notable omissions, as the Lunar Rocks in the bottom of the Great Crater; and some striking perversions of natural characteristics of the country, as the smooth broad slopes of the southern coast, rent here and there by precipitous barrancos. (See Photographs, Vol. X., Nos. 15, 16.)

A third map has been given to the world by Messrs BARKER-WEBB, and BERTHELOT; it is founded chiefly on LOPEZ, and other Spanish authorities, and, though strangely inaccurate in some of the geographical proportions, as the size of the Great Crater, is yet admirably stored with the results of eye observations made on the spot. Here, accordingly, we find the Lunar Rocks, the characteristic barrancos, and the streams of lava pouring down from the Peak, and inundating the Canadas. This map is in fact the impression of a naturalist, after passing through the country, seeing and noting everything, rather than the measurement of a mathematical surveyor taking account only of a few leading features, or of certain mean general quantities. So difficult, however, is it to seize all the innumerable points of this most complicated bit of mountain fabric correctly, that even these authors have failed in giving the true figure of the southern wall of the Great Crater; and, in place of showing Chajorra as one vast volcanic bowl, they have depicted two little ones, separated by a narrow ridge. Such, however, is, curiously enough, the appearance from Guajara more than 1000 feet lower; and it is only by going up to the culminating point of the Peak, and looking down on Chajorra from an eminence of 2000 feet, that the real interpretation of what is barely seen from below can be obtained. (Compare Photographs, Nos. 33, 34, Vol. X.)

The rival maps of Von BUCH and BARKER-WEBB with BERTHELOT, were the subject of remarkable discussions in the French Institute in 1837; and the later map was somewhat unfairly condemned in everything, when M. ARAGO was able to bring forward some rather indirect marine observations by Mr PENTLAND, indicating that the southern radius of the Great Crater could not be so large as the two associated savants had made it. Now, this radius, as defined by GUAJARA and ALTA VISTA, we had the opportunity of measuring directly, both by triangulation, and by latitude observations, with a sextant. The mean of the results, which came very close to each other, showed Von BUCH to be right to within $\frac{1}{8}$th of the whole distance, while the other map had erred by the whole quantity, or made the distance twice as great as it really is; and a third engraved sheet, since produced, has erred to the extent of $\frac{1}{4}$th in the opposite direction.

All the accuracy of proper trigonometrical surveying has thus evidently still to be applied to this land; and its due application might be repaid, by the exact understanding, which thence would follow, of the results of countless ages of first-class volcanic disturbance, which here lie slowly oxidising in brilliant colours, but not sensibly disintegrating, in the usually arid air of a mean height of 7000 feet above the sea, and 3000 feet above the Trade Wind cloud.

For present purposes, I have prepared the approximate maps and sections in Plates 30 and 31; also the stereoscopic plans on the title page, trying to combine the strongest points of preceding authorities, and assisting them here and there by my own observations.

(2.) *Leading Analogies.*

An important point in the aspect of Teneriffe has been seized on by Baron HUMBOLDT (Personal Narrative, Vol. I.), in "the smallness of the cone of ashes as "compared with the whole height of the mountain;" being, he says, with Teneriffe $\frac{1}{22}$d, while with Pichincha it is as much as $\frac{1}{10}$th, and with Vesuvius $\frac{1}{3}$d.

The proportions stated are, as I believe, perfectly true with regard to the parts of the respective mountains on which they depend, and much has been written on the conclusions thence to be deduced, as to the contracted limits of the earth's volcano-making power—exemplified, it has been thought, by the exceedingly small amount of material, lifted 12,000 feet high, to form the cone of Teneriffe—compared to the very much larger quantity, raised 3000 feet, in the construction of the Italian mountain. Confining ourselves, however, to these two extreme cases, we may be able to show, that the portions of either volcano contrasted are not strictly analogous; and that a considerable correction is therefore required in the above numerical returns.

The term Vesuvius, employed by the great traveller in his investigation, is evidently used in its popular signification, or as including both the Somma and the Vesuvius of geologists; the former being all the lower part of the mountain from the sea-level, or flat country, up to about 2300 feet of altitude, where it forms a broad, circular, and partly enclosed plain, in fact, an old and large crater, on the floor of

which rises the conical form of the true Vesuvius, 1200 feet high; thus making the whole height of the double mountain 3500 feet.

This case is sufficiently understood and allowed by all scientific men; but Teneriffe not having been so frequently visited as the Neapolitan volcano, there would seem to be still some rather erroneous ideas occasionally entertained as to its general configuration. To elucidate clearly what this is, we must examine the mountain as a whole; and we shall then find, on ascending from the sea-coast, a smooth slope at an angle of 12 to 14 degrees, conducting, at nearly half the whole height, or 7000 feet, over a precipitous ledge into an extensive plain, the "Great Crater." This is encircled on three sides, to an observer in its middle, by horizontally stratified cliffs; and has an immense cone—the "Peak"—rising near its centre, with the steeper angle of 28 degrees. In this elevated plain, and its concave line of cliffs, there can hardly fail to be perceived a certain resemblance to the Somma portion of Vesuvius, while its central cone or Peak stands for Vesuvius proper; and if, in carrying on the comparison with Teneriffe, we invert north for south; or consider only the direction of the nearest sea-board,—we shall find a series of most remarkable resemblances. Thus,—

1. The volcano is much nearer to one sea-board of the country than the other.
2. The wall of the Great Crater is higher and more perfect on the side most distant from the nearest sea-board.
3. The outward slope of the walls of the Great Crater is under 15 degrees, while the inner slope is often precipitous.
4. The walls of the Great Crater consist of dense and compacted strata of hard rock, and have, as the rule, no recent lavas or pumice.
5. The cone, rising in the centre of the Great Crater, is composed, externally, of loose ashes, overflowed here and there by narrow longitudinally defined streams of lava, which have issued from a crater above, and are generally found broken and comminuted on its steep-sloping sides.

Up to this point, the middle of the central cone, the comparison between the forms of Teneriffe and Vesuvius-cum-Somma may be said to be perfect; and one has only to introduce a larger scale in every way for the former, to describe it completely in the well-known terms of the latter. If we then continue to ascend, climbing the cones,—*i. e.*, the "Peak" of Teneriffe in one case, and Vesuvius in the other,—a difference will presently appear; for on the top of Vesuvius is a fiery crater-pit, still occasionally pouring out streams of lava; while on the top of Teneriffe, its once active crater being now filled up, we find only the so-called plain, or rather, convex surface, of Rambleta, surmounted towards its eastern end by a diminutive cone 500 feet high, HUMBOLDT's "ash-cone:" or, the "Sugar-Loaf" of many travellers. On considering, however, that Vesuvius, while a smaller, is a younger volcano than Teneriffe, and that it is going before our eyes through the career that

was completed by the latter, long before the advent of civilized man; and on finding, by observation, that the efforts of the Italian mountain are curiously directed to filling up its crater, and even to raising towards one end a small cone,—as is well shown in the faithful drawings of Sir WILLIAM HAMILTON, and of Mr AULDJO,—we may be assured, that if it does not in the end succeed in surmounting itself with a Rambleta, and a permanent Sugar-loaf cone, yet there was error in taking the mere terminal point of Teneriffe as the analogue, not of the nascent sugar-loaf in the crater on the top of Vesuvius, but of the whole cone or mountain, Vesuvius.

In short, then, the only "ash-cone" of Teneriffe, comparable with Vesuvius, is the huge mass that rises from the plain of the Great Crater, and has a height of 5000 feet, against the whole mountain's 12,200 feet, or rather its 15,000 feet, if we make a moderate allowance for the depth to which naval soundings show that the base of the volcano is still submerged in the sea; and then the proportion comes out ⅓d, or exactly the same as with Vesuvius and Somma.

3. *The Great Crater.*

The Great Crater which is found on Teneriffe, at a height of 7000 feet, and with a diameter of 8 miles, was first recognised as volcanic by M. CORDIER, and was afterwards included by Von BUCH in his examples of craters of *elevation*. On its external flanks it shows little but lateral extensions of compact basaltic lava and tuff, dipping outwards smoothly and uniformly, at an angle of 12°; while the section of its walls, as exhibited on their precipitous *internal* edge, displays an apparent horizontal stratification, the effects of a quaquaversal dip, extending for miles, and interfered with only by the occasional fall of part of the cliff, or by greenstone, and other dykes, radiating generally from the central position. These strata, varying from 500 feet to a few inches in thickness, are always felspathic, and, accordingly as magnesia or iron predominate, are found to vary in colour from white to blue, grey, green, brown, and red.

Mount Guajara, our first station, is the culminating point of the wall of this crater; and was found to have its summit composed of grey trachyte, often minutely laminated, and intersected occasionally with dykes of greenstone, and of a black lava with white crystals of glassy felspar, identical with the recent streams of the Peak.

An examination of nearly opposite parts of the rampart,—viz., S. and N.N.E.,—carried on by means of the front section offered on the interior face, and by the side sections given by large radial ravines,—proved a very strong general similarity of construction to prevail between them; and there were certain features, as a stratum of bright white tufa, about 300 feet below the summit, together with, somewhat lower down, a very peculiar sheet of hard but brittle greenstone, breaking up into little angular, half-crystalline lumps, of about one-third of an inch in the facet,—which were so remarkably repeated N. and S., that though now several miles asunder, they

had no little semblance of having once been portions, not necessarily contiguous, of the same original beds.

That the volcanic identification of the huge circle was reserved for M. Cordier may be due in some measure to the sheer vastness of its area, on which one might wander as in a broad country; and also to its never having been in proper action of its own, since its head was raised above the sea. It has undoubtedly been rent and dyked, and overflowed here and there with lava at a later period; but the origin of all these disturbances was the Peak, or central cone, raised in subaerial times, and sundry small eruption mouths, which have as recently broken through the broad flanks, here and there, without reference to, or dependence on, the figure or presence of the ancient crater.

In their assumed gradual rise out of the sea, the old submarine walls have been cut into by the waves at several heights, chiefly noticeable on the S., much as they are now being eroded into cliffs, in several places along the coast, by the present action of the surf. Towards the W. and N.W., again, large portions of the crater flank are concealed by streams of recent lava, and small eruption mouths; while to the N.E. a considerable sectorial portion, now forming the fertile valley of Taoro, is gone,—as if it had either sunk in, or been washed away, to a depth of about 1000 feet, and a length extending from the crater edge down to the sea-beach, or about 4 miles. Elsewhere the walls are pretty perfect, both inside and out, being only modified towards the S. by several deep ravines running out like radii, and on the E. by being banked up, in a manner, by a mountain ridge that forms the backbone of the island.

In Photographs, Vol. X., Nos. 8 to 31, many of the characteristics of the general structure and arrangement of the rocks of this great crater are given, and will be found sufficiently marked and distinct from all the more recent productions.

The submarine origin of the walls, concluded from many analogies, has lately had the positive proof, which had been much called for, afforded, in the finding of fossil shells on certain parts of its flanks, and specimens of them have been brought to Europe by various travellers. They seem to belong to the most recent part of the Tertiary age, as already ascertained by Von Buch for similar productions found, and more abundantly, in Grand Canary, Palma, and Madeira.

What, it may be asked, was the sort of volcanic action in this crater during the days of its activity; when, long before the erection of the steep-sided, central, subaerial Peak, it appeared as a broad-based, obtuse-angled, low, truncated cone, much like the figure of Somma in the days of Strabo? Considering, too, the size and platitude, we may also inquire whether the whole area was ever filled with melted lava, like the huge caldron of Kilauea, so well described by Wilkes and Dana?

This latter supposition, however, is at once negatived by the non-existence of the circumferential ledges so conspicuous in the Polynesian volcano. In the S.E. portion of the Teneriffe basin there is, indeed, a sort of step in the wall (see Photograph, No.

11), which looks at first much like a portion of such a ledge, and is duly noted by Von BUCH in his journal as something very remarkable; but we clearly made it out, after a while, to be a landslip of the upper part of the cliff. A landslip, however, of a very remarkable order; and more noteworthy still, in another similar instance to the S.S.E., where the columnar portion of the wall has sunk straight down into the earth, without leaving any heap of debris, and without there being any stream of water to carry away such a mass; and now the top of what was once the summit of the crater wall is seen erect, but almost engulphed in the ground, like the head of a man just disappearing in a quicksand.

This phenomenon certainly savours of a hollow beneath the surface; and though the idea is rather repugnant to our feelings, yet the fact of such volcanic hollows, from whatever cause arising, has been abundantly proved by the occasional sudden falling in of large mountains, in whole or in part, as Papandayang in 1772, to the extent of 4000 feet in a single night, and several others in Java and the Andes, as Galongoon, Carguairazo, &c.

Further, the preceding instances in Teneriffe are supported by many others there; as by the "Lunar rocks" under Guajara, or portions of the tops of the original walls, with their strata still nearly horizontal, but sunk almost level with the crater floor (see Photograph, Nos. 15 and 16); also, by some large bays, or, as their shape implies, conchoidal fractures out of the eastern wall, where the portion so broken out has disappeared altogether; and, finally, by the grand depression of the valley of Taoro. This latter, indeed, might be claimed by some as the effects of aqueous erosion; but that view is weakened, and the doctrine of its having sunk much strengthened, on finding beneath the lava-inundations which have poured down the hollow in recent geological times, the same "tosca" stratum, which forms the upper surface of the still undepressed flank on either side.

(4.) *Central Cone.*

As soon as, in ascending from below, one enters the broad plain of the crater just described, the ground is found to be abundantly strewed with ochry-coloured pumice-stone in minute division. This substance, however, together with the many rough broken streams of lava which occupy the plain on every side, is the product of the comparatively small subaerial cone, rising near its centre, and forming the Vesuvius of Teneriffe.

The angle of slope in this cone is more than double that of the Great Crater, being on an average about 28° on the eastern side, where we ascended, and is probably more N. and S.; on account of the mass being somewhat elongated into a ridge form running W. and E., by two side protuberances or "axes of volcanic activity." That on the former side is Chajorra, a magnificent crater (see Photographs, Nos. 33 and 34), some three-quarters of a mile in diameter, 500 feet deep, and attaining a height of about 10,000 feet above the sea; while that on the latter side is Montana Blanco, which

has no open crater, but presents only a huge rounded mound of yellow pumice, with streams of red viscid lava exuded through it here and there, and attains a height of a little more than 9000 feet.

The central of the three heads rises to 12,200 feet, or, if we disregard the terminal sugar-loaf, to 11,700 feet, forming there the crater of Rambleta, not far from a mile in diameter, and fringed all round with black streams of lava, most of which have descended so little as not to reach the pumice plain, and hang round about the cone, as Von Buch has remarked, like black ribands.

Chajorra has a few of these black streams also; and the last eruption of the mountain, in 1798, produced a stream from a rent in its western side, said to be pure obsidian, and certainly looking remarkably black from Guajara. But the most noteworthy feature about this crater was, perhaps, the remnant of an ancient filling up, still adhering to its southern side, indicating that it was then brimful, perfectly level, and the material, when cold, extremely hard, as shown by the depth of precipice it now forms compared with the other portions of the wall (see Photograph, No. 34). Chajorra, in fact, does show symptoms of a once resemblance to the present Kilauea of the Pacific.

Wherever we came on the black streams of lava, they were found utterly broken up into separate blocks, and though amongst the penultimate streams were seen a few of obsidian, forming sheets for small distances, as close to our station at Alta Vista (see Photograph, No. 36), yet the *rule* for all the lavas poured out by the central cone, either from its principal mouths, or any of the numerous vent-holes about its flanks and feet, and equally for its earliest and its latest exudations,—was, that they were in the " broken up" condition ; *i. e.* on, and close to, the surface, that being the only part which we were enabled to examine.

The relative ages of the lavas, first ascertained by order of superposition, was indicated also by colour, the black passing into red, and then into brown-yellow, with increase of time. These colours, however, were but skin deep; and in this superficiality of oxidation the cone streams were perfectly different from the lavas of the Great Crater walls; take those of Guajara, or the Lunar Rocks, for example, where the light surface tint prevailed through and through. The same sort of progression was likewise shown, and in an interesting manner, by the pumice portion of erupted materials—being, on the surface of Alta Vista, glassy and bright; below the surface and on the plain, rather dull; while some found on Guajara looked quite powdery, and ready to fall into dust, though the forms of its original filagree-work of once ductile threads still remained entire.

On the whole, a certain unity was perceivable, connecting the old and the new craters, accompanied, however, by a decided secular change, operating no less on the size of the effusions than their mineralogical quality. This latter is shown by the occurrence in both of glassy felspar crystals, which, exceedingly minute, and almost microscopic on Guajara, become larger and more numerous in every later eruption,

until some of the last exudations from Rambleta show little else than congeries of the white crystals, cemented together by the black interstitial matter.

Where the lava assumed the state of obsidian, its condition with regard to the white crystals of felspar was most instructive; for the obsidian of Guajara, or the ancient, was fine uniform black glass, capable of forming keen cutting edges; while that of Alta Vista, or the modern, though quite as glassy, was yet so contaminated by the presence, in an unaltered form, of the white crystals, as to be rendered utterly friable, and inclined to break into little cubical or angular lumps. (See specimens of these obsidians, and other Teneriffe rocks collected during this investigation, and deposited at the British Museum by the Lords of the Admiralty in July 1857.)

Confining our attention, however, once more wholly to the central cone, and its effusions, which we had an unusually good opportunity of overlooking, almost as in a map, from our station on Guajara, we may affirm decidedly, that signs of secular as well as periodical change were brought out there also within the subaerial period, and not only in volume,—the yellow lava streams being always larger than the red, and the red than the black,—but also in their primitive heat and consequent manner of flowing, as shown by unmistakeable dynamical records. The yellow variety, for instance, had spread far and wide over the almost level plain, and formed itself into transverse curving edges or forms rudely like waves on the sea-shore (see Photograph, No. 11). The red streams, again, had not spread so much, and looked like great sluggish overflows of thick viscid mud; their transverse wrinkles were very faint, much like those of a glacier; and they had beginnings of a longitudinal system of markings, nowhere seen in their predecessors. Finally, the black lava showed no transverse arrangement at all, but only a culmination of the longitudinal marking, which stretched them out into long, narrow, axial ridges, often looking like railway embankments; and instead of conveying the idea of any sort of fluid motion, suddenly frozen, appeared in the distance like sand, or hard dry matter in a state of minute division.

Distance was everything in making this induction, for all the three classes of streams, when examined closely, consisted equally of loose broken blocks; and the scale on which they were heaped up was so tremendous, and the manner so savage, that no horses could have been employed in their local examination; and it would have been a very long time indeed before a surveyor, painfully walking on foot amongst the rough rocks, would have been able to make out their general laws of distribution over a wide area. But the bird's-eye view commanded by our astronomical observatory on Mount Guajara, assisted by the hypsometric shading of morning and evening suns, enabled us, with comparative ease, to arrive at these broad results, of what may be called telescopic petrology, and in a manner much more applicable to questions of the lunar surface than the ordinary observations and measures of the geologist.

(5.) *Ice Cavern.*

Situated among the broken streams of black lava on the central cone, at a height of 11,045 feet, this subterranean cavern, whose only entrance is a small hole in the roof, has excited some inquiry as to the origin and reason of its perennial supply of snow.

The origin would appear to be simply, that the snow is driven in every winter during the storms which then whiten the whole Peak down to a height of 6000 feet; and the supply once in (after all but a small heap on the floor), it is protected by the stony roof of the cavern from the direct *radiation* of the sun, which, at the local elevation, is a most important melting element to take into account. At Alta Vista, for instance, 300 feet below the Ice Cavern, we found the temperature in the shade 48°; when in the sun it was above 180°. The situation, moreover, is so little below the line of perpetual snow, that there were not far from it two large white patches on the southern side of the Peak, exposed to the full radiation and temperature combined, and they lasted under our eyes to the third week of July. Hence the cavern is only, as previous writers have sometimes described it, a natural "ice" or snow "house," and in a locality where any other partly-roofed chamber would soon get similarly stored.

The snow-heap, when we examined it in September, was in a very moist condition, a sort of sodden mixture of hail, snow, and water (see Photograph, No. 51), and seemed to have melted considerably; the water so produced running off to the end of the cavern, and forming an underground pond of notable size.

This retention of water struck one as not a little remarkable to occur in the midst of the Malpays, a region of loose broken stones; and an investigation of the circumstances, besides showing a layer of winter ice under the water of the summer's melting, led to some interesting and unexpected geological conclusions.

The entrance to the cavern is effected, as already described, at a hole in the roof, by lowering oneself with a rope some 20 feet. The interior is then discovered to be of a dome-shaped figure, with three long, descending, and contracting conical channels (see Woodcuts), the smoothness of surface of the whole interior looking like a specimen of the plasterer's art, save some few rents in the spherical ceiling where infiltrating water has honey-combed the edges of the lava, and here and there where some large lumps have fallen to the floor.

Turning, then, to the exterior, that was found to be as remarkable for its roughness, being rent and cleft in the most inconceivable manner; so that, working our way over it, we could not fancy the existence, immediately below, of the large cavern with its long water-tight arms of regular figure, extending W., N.E. and S.S.E., some 70, 50, and 30 feet respectively, to where their descending roofs meet the general water-level (see Photographs, Nos. 49 and 50).

Careful examinations of the lavas proved, before long, that the site of the cavern had been the place of emission of one of the ultimate class of lava streams; for, following its course downwards to the east, the blocks became more and more rounded

by attrition, smaller lumps appeared, and at last considerable quantities of gravel and dust, the products of attrition. Tracing the stream upwards again, one perceived clearly

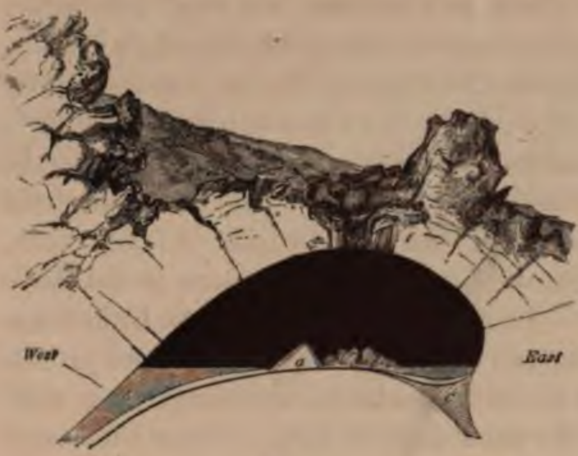


Fig. 1.

Approximate vertical section of Ice Cavern from West to East.
a. Snow-heap—*b.* Water—*c.* N.E. arm of cavern beyond plane of section.

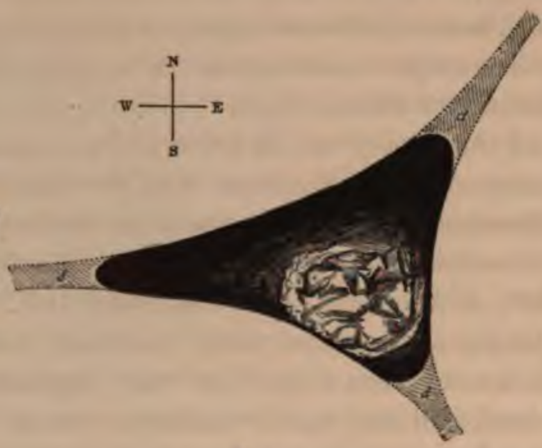


Fig. 2.

Approximate horizontal section of Ice Cavern, at one foot below water level.
d. Arms of cavern descending below the plane of section.

a gradual sharpening of the angles of the blocks, an increase of density and toughness of material, and then, on coming very close to the Ice Cavern, the symptoms of their being found almost *in situ*, inasmuch as they exhibited on their tops the frothy corrugation of an incipient pumice. At and over the cavern-site the general form of the mass was convex; and the various rents exhibited the effects of a central force from below, the corrugated surface inclining outwards on every side, even toward the cone, while some few isolated blocks had been fairly pitched out of their places, but in a direction conformable with the above, and to distances of only a few feet.

These local proofs of the cavern, as a centre of action, were further testified to by a stream of lava which had been coming right down on the place from the Rambleta Crater above, and had stopped suddenly short, and piled itself up into a steep front of rocks, as if it felt some powerful resistance in its path. (See Woodcut, No. 1.)

There seemed also testimony to the throe that had produced the spherical form over the Ice Cavern, and tossed the blocks out to all sides, being the *last* that had occurred; for the said blocks, though sometimes inverted, were found close to their cavities, and with their angles perfectly sharp, and without any abraded matter about.

Now, simply putting all these phenomena together, we can hardly be led to any other conclusion, than that a long lava stream poured for a time out of the site of the Ice Cavern, and that as the last of the lava came forth, a gradually accelerating expansion of gases, uniting from their different sources, raised a grand sort of bubble over the place—the cracking and partial falling in of whose roof immediately afterwards instantly liberated its charge of vapours.

The very rent and fissured nature of the exterior indicates that the crust had

cooled down to hardness; the smoothness of the interior attests there a full plasticity from heat and pressure of a tense gas; while the three tubes coming *upwards* from three different azimuths, none of them the direction of the exuded stream, enlarging, too, as they come, and finally uniting in one dome,—speak of the united effort of so many compressed columns gradually overcoming the resistance that had previously restrained them.

The gas need not have been of a permanent nature; steam at a high temperature and pressure would have been perfectly efficacious, and is still abundantly ejected from fissures in the terminal crater of the mountain, and in the neighbouring malpays; while even from the centre of the floor of the cavern, where the middle of the snow-heap by the way is very suspiciously melted out, we perceived, when photographing, a slender little column of vapour to rise for a few minutes.

A consideration of the several circumstances will at least show that the Ice Cavern is something very different from the ordinary tubular caverns, formed simply by fluid lava escaping by gravitation out of its hide-bound crust; and the elevation of the cavern-roof, by gaseous pressure, is the only explanation which appears to account for all the features. If this eventually proves to have been the fact, the case will be most invaluable, as observers can enter the cavern, and as it were examine into Nature's secret processes below the surface, or behind the too solid curtain which usually conceals everything but the final results; and the whole cavern will then require a complete survey both inside and out.

(6.) *Ice and Water Action.*

The recent development of glacier and iceberg influence in geology demand renewed examination of many countries well described in former days. In ascending Teneriffe, accordingly, we were on the out-look for traces of such action, and from the height of 3000 to 6000 feet perceived remarkable polishings, groovings, and grindings in the central line of the great ravine in the valley of Taoro. The rock was basaltic greenstone-lava, excessively dense and hard.

These scratches were eminently different from those we afterwards found on lava masses that had apparently rubbed together in a semi-plastic state in the Great Crater; and also from markings in the upper parts of many small ravines, where the water appeared to have been a great carrier of stones and abrading materials. But, then, why should such glacier-like indications be confined to a breadth of one or two feet in a ravine many hundred feet broad? It might be perhaps partially accounted for from the circumstance, that the breadth of the ravine, as it exists now, is mainly due to the serious deluge of 6th November 1829. Water then rushed down the valley of Taoro in unprecedented volume, and in a few hours tripled the breadth of the great ravine. The material was so hard, as to have defied for ages all the *wearing* power of water and stone; but it was *broken up* in a few hours, by undermining apparently, and by the water entering the fissures; while huge blocks, which

the water detached, but could not carry away, are still to be seen thrown about in wild confusion. This breaking-up action of water, leaving a rough and angular surface,—strongly opposed to the smoothing effect of ice,—is also to be seen in the small bay to the west of Orotava, and is the produce, as already mentioned, of a single storm of last winter, when the wind blew strong from the N.W.

On the whole, then, from the grinding and scratching observed in the ravine, the former presence of a glacier was not proved; but when afterwards, in a ravine near Santa Ursula, we found large grooves, 3 to 9 inches broad, driving through the roughness and smaller sinuosities of the rock in long lines, following the general direction of the valley, there did appear to be some positive testimony.

The great deluge of November 6, 1829, is still spoken of with fear by the inhabitants, and those with whom we conversed in the Orotava district would not hear of its having been produced by anything but a "water-spout," on account of the suddenness and little warning with which the torrents of water came down. But inasmuch as the whole island was visited more or less by unusual violence of wind, if not of rain, and as the barometer at Laguna (see BARKER-WEBB and BERTHELOT) was remarkably affected before the storm began, there would seem to have been something more general and less anomalous in the case than a water-spout.

The Orotava people, too, were somewhat on the lee-side of the island at the beginning of the storm, and this may explain why they did not feel much wind. While that they were deluged with torrents of water from the upper parts of the mountain, without having had any notable rain falling on them, is but in accordance with our remarkable storm at Alta Vista on Sept. 14, 1856 (see pp. 528, 529), when two inches of rain fell on the mountain top with a south wind, and not a drop fell in Orotava. Those two inches were all absorbed by the thirsty soil; but had two more inches fallen above the absorbing power, it is evident that the inhabitants below would have been astounded by seeing unexpected cataracts descending the mountain; and there is, in fact, no complete understanding of meteorology to be obtained, even for practical purposes, without observing the phenomena of the upper, as well as the lower, strata of the atmosphere; or, in other words, maintaining an observatory above the level of the lower clouds.

(7.) *A Site for Attraction Observations.*

If observations for the density of the earth by the attraction of the Peak of Teneriffe on the plumb-line are to be made,—as proposed in the "Suggestions,"—a N. and S. will be more suitable than an E. and W. direction; for the western side of the volcano dips rapidly into the sea, while the eastern has a mountainous prolongation of many miles. There is some difference in the configuration N. and S., but it is not very important.

The mean configuration, however, is unfavourable, the form being a low pyramid, with an angle of elevation of only 12°; and its mass hollowed out at the top, and

detracted from, by the pit of the Great Crater, 8 miles in diameter. At the same time, its internal constitution is most uncertain.

The geological arrangement being, so far as known, in layers more or less parallel to the surface, is only exhibited in section, and is therefore only exactly determinable for those small depths comprised within the walls of the crater or the sides of ravines. Now, this portion containing in its strata and dykes some of the heaviest and lightest rocks known, basalt and tuff, obsidian and pumice, in anomalous positions and quantities, leaves the constitution of the mass of the mountain a very uncertain problem indeed, even if its volcanic nature were not taken into account, or if the volcanic action should long have ceased. But when to this we add, that the fire of the mountain is not extinct, and breaks out from time to time in a manner that indicates the whole island to be undermined,—Von Buch has aptly compared it to a glass furnace, and the various lateral eruptions to bricks being knocked out, now on one side, now on another, and so giving vent to portions of the general internal flame,—it does appear that the Peak of Teneriffe is a very untoward place for determining the density of the earth. So much so, indeed, that it is not necessary for me to enter into the enormous expense which would be incurred in the accompanying minute survey that the attraction observations would require; an expense which, the height of the mountain, its rugged character, and waterless condition throughout the summer, would increase far above any precedents derivable from England or Scotland.

(8.) *Volcanic Theories.*

Under the present advanced condition of scientific theory, I should hardly have ventured in this Report on any discussion of geologic doctrines, had not the Royal Society's list of suggestions, incorporated into my official instructions, encouraged me thus to lay before our best geologists some considerations that were brought up by force of circumstances to my notice when on the Peak, in far too remarkable a manner to be altogether put on one side.

That Teneriffe is not yet known in this country as well as it deserves to be from its standing in nature, we may well conclude, on finding it to occupy only one page and a-half in that approved standard work, Sir Charles Lyell's 'Principles of Geology' (7th edition), when the two smaller volcanoes, Etna and Vesuvius, fill together more than 50 pages.

Looking to French and German literature on Teneriffe, our own seems peculiarly deficient in modern scientific records; and it is therefore not a little surprising how so admirable a work as Von Buch's 'Canarischen Inseln' has escaped an English translation. There, at least, was one of the ablest geologists of his time, as well as one of the most extensively experienced of volcanic travellers, spending not the usual one or two days of most visitors, but many months, first investigating the phenomena of the Peak, and then describing them with the ease and fluency of a professional writer, as well as with the freshness and point that mark the original observer. To

the accuracy of his descriptions, also,—and his was not the first work on Teneriffe that I came across,—I can in some cases bear direct testimony, having repeated several of his lines of march, and compared his descriptions with nature. In his more theoretical writings, the comprehensiveness of his grasp of many and varied phenomena is not a little remarkable; and the skill with which he strips off the mask of petty accidents and extraneous circumstances, showing the broad and all-pervading laws of nature acting below and through all, speaks of nothing less than a master-mind in his science; not always right, certainly, as what man can be, but ever great and true and honest to his facts.

Such a man is always to be read with advantage; and therefore it is again to be regretted that his later and greater works have not appeared in our own language, to speak for themselves to a wider audience than an untranslated book can ever command. Had this step been taken, we could not have had this eminent author so run down, as he strangely is in many English geologic works of high repute; where it is not too much to say, that his theories are first unconsciously misrepresented, then on such data proved unsound; and finally, he himself is deprived of all rank and authority in his favourite science.

A part of his theory refers to the effects of "elevation force" in volcanoes, producing in certain cases what he called "elevation craters;" and he showed that the Great Crater in Teneriffe might be placed in this class. This, however, Sir C. LYELL will not allow, because, says he (p. 419, 'Principles of Geology,' 7th edition), "if, "according to the elevation-crater hypothesis, a series of sheets of lava and ashes, "originally spread over a level and even surface, have been violently broken and up-"lifted, why do not the opposite walls of the chasm correspond in such a manner as "to imply, by their present outline, that they were formerly united? It is evident "that the precipices on opposite sides of the crateriform hollow would not fit if brought "together, there being no projecting masses in one wall to enter into indentations in "the other."

From this clearly-worded passage we must surely conclude, that, according to Von BUCH'S theory, the opposite crater walls should have been, immediately after their formation, exact counterparts of each other; and should be so still, as there is no other cause known to Sir C. LYELL capable of accounting for a present want of fit, except that the theory is not true, or does not obtain. Turning, however, to Sir CHARLES' 'Manual,' 4th edition, p. 393, we find that there he dwells much on the disfigurement suffered always and necessarily by great craters of similar geological history to Teneriffe, as they rise, after their volcanic formation, whether by elevation or eruption, above the surface of the sea; and applying this principle to the neighbouring crater of Palma, he concludes with, "Can we doubt that the same power" (waves and tides) "may have cleared out much of the solid mass now missing in the Great Caldera."

Hence the want of fit *now* found is really, after all, according to Sir CHARLES himself at another time, no reason why Teneriffe should not have been an "elevation

crater," even had that theory demanded, as he implies, that the opposite walls should be exact counterparts of each other. But does it do so? Referring for this to Von BUCH himself, in his revised edition of BOULANGER's French translation of the 'Canarian Islands,' we read at page 323, that, according to his views, the formation of an elevation crater is owing to the *falling in* of the upper part of the elevated crust, "une partie," says he, "au moins, retombe sur elle même;" in fact, the area of the crater having tumbled in, and being engulphed, the existing opposite sides could never have touched, or had any immediate connection with each other; and Sir CHARLES argues against himself when insisting so particularly, as he does, in the 'Principles,' that the opposite sides of the Teneriffe crater really do not fit, or "would "not fit if brought together, there being no projecting masses in one wall to enter into "indentations in the other." But how, we may ask, are all the opposite sides of a nearly circular area to be brought together, and at the same time have all their innumerable linear irregularities preserved in full size? The two sides of a longitudinal crack might be so approximated; but the case proposed in the words above quoted is simply a practical impossibility.

Many other similar instances might be brought forward from that otherwise so highly and deservedly esteemed work, showing that it has not a little failed in expounding Von BUCH's theoretical views. What they are, and what, therefore, constitute forcible arguments, *pro* or *con*, must be taken from Von BUCH himself. Of Sir CHARLES LYELL's distinguished ability, and of his wish to act fairly and philosophically in questions of this nature, all the world is perfectly aware; and it is owing, not improbably, to the influence of his great name, that Mr POULETT SCROPE, in the last edition of his own work on the 'Geology of Central France,' denounces in the following terms "that most unphilosophical theory of elevation craters, first "suggested by M. de BUCH, and afterwards warmly espoused by MM. ELIE de "BEAUMONT and DUFRESNOY. Next to the exploded theory of WERNER," says "he, "I know of no fallacy that has so much impeded the march of true science, "or been so obstinately persisted in. Such a notion could only find favour with "geologists who had never witnessed the phenomena of volcanic eruptions on a large "scale, and consequently had no conception of the normal manner in which their "products are disposed. To one who has had that advantage, the theory does not "appear to merit any serious discussion."

"Pushed as it has been to extremity," continues Mr SCROPE, "by the two last-"named authorities, it in fact denies a volcano to be eruptive at all, that is to say, to "be productive of any appreciable amount of lava or fragmentary matter."

Hereupon, let us turn to the two authorities named, in their admirable memoirs on Etna and Vesuvius, and we immediately find chapter after chapter on the materials of eruption of both mountains, and descriptions of streams of exuded lava covering many square miles; and in M. DUFRESNOY the following concise passage, "on peut donc supposer,—que la colline du Monte Nuovo, soulevée à une certaine hauteur, a

ètè exhaussée en 1538 par une eruption à la fois de gaz et de scories, de maniere à presenter la forme de deux montagnes projetées l'une sur l'autre."

This passage is all the more important, as it indicates the sense of elevation-crater theorists upon a frequent cause of misunderstanding among their opponents, who, on examining the exterior of a mountain, and finding " eruption" materials, say, with a mixture of truth and inconsequence, " elevation" could not have produced these, therefore the elevation-crater theory is untenable. Thus Sir C. LYELL, in a paper recently read before the Royal Society, demonstrates that Etna had once another chief axis of eruption than the present one, which forms the culminating point of the mountain, and was at a distance of three miles from it; and that the former has been overflowed and buried by lava streams exuded from the latter; now this, says he, which he calls the doctrine of the double axis, is something which elevation could not accomplish, therefore Etna is not an " elevation crater." But, bearing in mind what Von BUCH's own representation of his idea of elevation and elevation-craters is, we see immediately that an internecine war of the eruption cones, subsequently raised on a mountain of elevation, does not touch the question of previous elevation in the slightest degree; for eruption, according to Von BUCH, may, and generally does, very closely follow elevation.

Even had we not, however, the light of this great man's writings (he is now dead, as well as his follower, M. DUFRESNOY) to guide us in ascertaining what his views really were, we can hardly think that Sir CHARLES LYELL's new doctrine of the double axis of Etna can form an argument of very cogent character, when in his 'Principles,' 7th edition, p. 400, he argues as positively for Etna not being an elevation crater, on the ground that it is *not* a double-axis mountain; or, because, in his own words, " the great centre of eruption was always where it now is."

Some such indications as I have just attempted to give—of the place of Teneriffe and Von BUCH in our literature,—appear all the more necessary, inasmuch as I had no sooner confessed to a conviction, from what I had seen in the field of elevation as well as eruption having left perceptible traces on the Peak, than I was treated, though at a great distance, much as the eminent German geologist has been. To prevent further misunderstanding, therefore, I am compelled to begin the next section with some general definitions of the terms here employed in volcanic induction.

(9.) *Elevation and Eruption.*

By *Elevation* effect in volcanoes, then, we designate a raising of the previously existing surface of the ground by pressure from below; and by *Eruption* effect, a raising of its acting surface by the spreading out, or heaping up, of new materials upon and over it.

These effects, not improbably the results of one and the same general cause acting under different conditions, are evidently, in so far, of a nature very distinguishable from each other, but are both of them similarly independent—of time, that is, the

effect may be produced more or less suddenly or slowly—of extent, or scale as to size—of the chemical nature of the materials operated upon, and of their height, or position above or below the sea-level.

Eruption effects are the easier to observe, for the phenomena present themselves bodily, in the shape of lava streams or rapilli, or showers of cinders coming either slowly or quickly out of a volcano's mouth, and are not to be mistaken.

Elevation effects, on the contrary, are of a recondite nature, and difficult to appreciate, for nothing appears on the surface, and the effect usually goes on very slowly; they are, however, felt over a greater extent of the earth's surface than the consequences of eruption, and have had a greater share in regulating those manifold changes which the earth's crust has undergone, to fit it for human abode. To "elevation," for instance, are owing those varying inclinations through long periods of time of large, and, we may safely say, of all parts of the terrestrial surface, making what was once deep-sea bottom afterwards dry land, with rocks of compressed and hardened alluvial matter, which is the basis of all geology, and which is going on actively and extensively still. Witness the sinking of Greenland on one side of the Atlantic, and the rise of Norway on the other; witness, too, the very rapid rise, geologically, of South Africa, or those great areas, here of subsidence, there of elevation, made out by Mr Darwin, as progressing among the isles of the Pacific.

All of these examples are slow, say a foot in 10 or 20 years, and seem to be carried on by imperceptible changes, without commotion; but it is otherwise when the movement is quicker, say one or more feet in a night, and more circumscribed in its area, for it is then generally accompanied by earthquakes, and by eruptions from the nearest volcanoes, as at Valparaiso in 1822, Cyprus in the same year, and at Conception, Talcahuano, and Santa Maria in 1835.

This latter class, as well as the former, are cases of pure elevation, perfect according to our definition, and admitted as facts by geologists of every creed.

There is also a third class, where the movement is quicker still, and where the crust of the earth, previously merely stretched and elevated, becomes strained beyond its powers of tension, and then, at some one point, is actually broken through. The commotion accompanying such a movement is, as might be expected, of the most violent order.

This sort of culmination of efforts long directed to a certain end, and perhaps only enabled to reach it by concurrence of many favourable conditions, occurs but very rarely, and endures then for so short a time, that no instance of it has been witnessed in actual operation by any competent geologists, though many have come on recent traces. Immediately after their production, too, such elevation phenomena are pretty sure to be overloaded and almost concealed by eruption effects following; and hence it is that Jorullo, though stated by Humboldt clearly enough to have swelled up like a bladder the night before its eruption in 1759, is denied to be a case of elevation by Lyell and Scrope. Monte Nuovo is also denied by them to be such, though claimed by Von

BUCH and his friends, and testified to by many others; as very lately by my respected friend, Mr C. MACLAREN, who found, by careful observation and comparison, that the internal sides of the crater showed the same stratification as their surrounding plain; but at such an angle as proved them to have been bent upwards from every side at that point, or, in other words, to have been "elevated." Dr DAUBENY has likewise shown, in his valuable work on volcanoes, that elevation must have preceded eruption at Graham's Island.

Though most persons may be satisfied by these instances, yet the amount of direct testimony is not so great, but that our example of the Ice Cavern on Teneriffe must be received as a valuable addition to knowledge; not, certainly, that it was seen in formation, but that it is of a unique character, admitting of examination both inside and out; for saved, by happy proportions, from the roof being either blown entirely off, or wholly tumbling in, and protected, by its lofty situation and dry climate, from most of the destructive effects of atmosphere, the impress of volcanic force is as perfect as if it had only just been exerted. Hence, not only do we find an indubitable convex surface of elevation, but we may descend beneath that surface, and measure the space through which it has risen, as well as speculate pretty securely on the proximate agency of the force of elevation.

This brings us to an important part of the subject; for though elevation would still be elevation, whether the crust was pushed up from below by a solid, a fluid, or a gas, yet some different features will be produced in each case, which the aspect of the country may confirm or refute. If here we may be allowed to take somewhat of an *à priori* view, it will appear that the greater calorific expansions, and the superior volume occupied by all bodies when in the gaseous, rather than the fluid or solid state,—the principle, indeed, that gives energy to the steam-engine, with room and verge enough for leakage and friction,—would indicate gaseous pressure to be the chief moving agent in elevation; for mechanical power of this order must be produced in superior quantity to any other, where or whenever large portions of our earth-ball are exposed under close confinement to a powerful heat.

Next, if we look to the actual facts of volcanism, we shall find this theoretical conclusion well supported in nature by the impetuous torrents of vapour, carrying along with them erupted materials of every sort, which generally succeed the formation of an aperture in an elevation-protuberance; and, finally, if we turn to the interior of the Teneriffe Ice Cavern, with its three smooth-sided, trumpet-mouthed, radial arms, joining altogether under the upheaved, dome-shaped roof of lava, we have as indubitable a proof as could well be desired, that gaseous pressure in large united volume had been here actually in operation.

So clear an example may surely be expected to produce some modification of opinion amongst opponents of Von BUCH; and certainly does not countenance Mr POULETT SCROPE, when he writes at p. 51 of his 'Volcanoes of Central France' (new edition):—

" The part of Von BUCH's theory with which I agree the least is, his supposing " these hills to be hollow, and blown up like a bladder. I imagine, on the contrary, the " aeriform and highly elastic fluids, the expansion of which elevated the lava, to have " remained chiefly where they were generated, viz., in a state of uniform and intimate " dissemination throughout the texture and between the crystalline particles of the " porous and elastic mass ; and not by any means to have united into one great bubble " or dome beneath an overlying crust of lava, as is implied in Von BUCH's theory."

Having now, however, obtained, by indubitable facts, the existence of " elevation" force, and effects, on a large and small scale in space and time, and procured a trustworthy insight into the habitudes and manner of acting of gaseous power, let us consider that much-vexed question of the Great Crater of Teneriffe. May it, or may it not, be called an " elevation crater ? "

Without discussing some of the objections that have been raised by certain writers, and which vanish the moment they are confronted with our definitions, we may take this one feature as conclusive, viz.,—all the materials of the walls, and all the outer flanks or crust of the mountain, whether erupted or otherwise, were poured out and consolidated beneath the sea ; and now we find what was once so low, towering, at its highest point, upwards of 8900 feet above the surface of the water. What, then, could have produced this effect, or rather, what is this effect and this great and acknowledged fact but "elevation."

The question of the submarine origin of Teneriffe no longer depends only on the general structure of its lava beds, or on analogies from the fossiliferous strata of the adjacent islands of Grand Canary and Palma, but has now the additional and most unanswerable argument of fossil shells having lately been discovered about the slopes of the crater. Why the anti-elevationists opposed so long the indirect evidence, and insisted that a shell must be discovered on the mountain of Teneriffe itself, before they would allow any one to speak of subaqueous formation, it is not easy to conjecture. We, in our own country, had lived in it for ages before any shells of the Old Red Sandstone were discovered, and even now they are few and far between ; yet no good geologists denied the submarine deposition of that important stratum ; nor do they even now deny such an origin to those of its beds which are still unfruitful of organic remains. Why, then, apply a different rule to the strata of Teneriffe, especially when they are of extreme untowardness, mechanically and chemically, for the preservation of fossils, and have never had the advantage of a tithe of the geological examination so abundantly expended on our own rocks, long thought barren ? The proof, however, of fossil shells, so long demanded, has now been supplied, and with them must be accepted the fact of the slopes on which they rest having been once submarine, though now subaerial.

The Great Crater, then, having incontestibly suffered elevation, was that elevation necessarily connected with its present form and character ? To this we may answer,

that those symptoms of the area of the crater, and part of its flanks, having fallen in, detailed at p. 540, both make it an "elevation crater," according to Von BUCH, and indicate the action of expansive gases as the immediate agency employed; for the moment these have stretched the soil beyond its limit of tension, they escape at the smallest crevice, and the unsupported roof, if large, *i. e.*, broad in proportion to its thickness, must inevitably give way and tumble in; completely realizing in this manner Von BUCH's admirable words, "aprés le soulèvement d'une masse aussi con- " siderable, unepartie au moins retombe sur elle même, et ferme bientôt l'ouverture " par laquelle l'action volcanique s'etait frayé un passage." What with this falling in, then, of the highest part of the raised crust, and the subsequent boiling up of lava exudations under other parts, it is probable that little of the old elevation hollow is now left; yet neither this circumstance, nor the covering of its outer slopes by eruption materials, can annihilate the previous great fact of "local elevation" having once taken place—an elevation, too, which though circumscribed in area, so as to make the region of Teneriffe a sort of blister on the surface of the globe, is yet so vast in actual amount, that the idea of its having been produced by the "dykes," so very rare as they are, does not admit of mention after any attempt to calculate the proportion they bear to the whole mountain.

Subterranean hollows, nevertheless, are still existing in some localities; for portions of them have been occasionally manifested by extensive and sudden subsidences, as at Carguairazo in 1698, Papandayang in 1772, and Galongoon in 1822. It is true that they are sometimes attributed, on the sole eruption view, to exuded lava-streams leaving a vacant place behind them; but hollows so formed must be at such extreme depths, and approached only by such long thin veins or pipes, according to the anti-elevation views of Sir C. LYELL and M. HARTUNG (see HARTUNG's 'Geologischen " Verhältnisse der Inseln Lanzarote und Fuertaventura,' Plate XI.), that the roofs could not fall in with the clear and decided symptoms of the volcanoes already mentioned; while, on the other hand, the observed subsidences being given, a thinness of roof, or precisely what would render "elevation" more probable, is intimated thereby.

We may be met here again by the supposed difficulty, that elevation ought to produce a star fracture (LYELL's 'Principles,' p. 356), and not a crateriform hollow; but such idea would appear to overlook, not only certain mechanical principles of stability in the dome, as contrasted with the arch, but the effects also of long-continued small progressive efforts (like the successive stampings adopted by manufacturers to produce at last a deep embossing in metal plates), and the potent influence of heat, which is capable of giving to trachyte rock even more than the flexibility of red-hot iron.

Now, these agencies of continued small elevations, assisted by heat, and superadded one to the other through long successive ages, are precisely what are taking place in nature; and with reference to the thermic element, it is not a little remarkable, that

in the immediate neighbourhood of the place, Monte Nuovo,—where, according to a preponderance of historic and scientific testimony, the ground once swelled up like a red-hot bubble of glass, broke through at the top, and then discharged an immense quantity of vapour or gas, carrying along with it showers of rapilli,—a transfusion of heat through the soil is again occurring, and to a degree, and with an intensity, to excite no little alarm.

This fact, observed by Mr Airy in 1856, was communicated to me without any reference to crater theories; and he remarked, with reason, how extraordinarily powerful the heating influence must be, when its effects could rise up through the sandy bottom of the sea at Baiæ, and be felt with that intensity and power found by him, almost, if not quite, in contact with the great cooling medium of the waves.

In truth, the consequences and effects, as well as the agencies of, and preparations for, "elevation," are so abundantly manifested in nature, that we might well proceed to consider—did space permit—whether that same force may not have assisted in raising and shaping the central, as well as the environing, cone of Teneriffe. That the former is now covered with eruption materials is no objection, for so is the latter; and if its lava streams are mostly broken up in place of forming solid beds, and are at a general angle of 28° in place of 14°,—both these differences may, and must partly, be results of volcanic action, under the atmosphere rather than under the sea, and on a scale in the one, some seventy times smaller than in the other. The contracted limits, however, of this report, prevent my doing more than calling attention to the difficulty of finding either any great and intense amount of elevation without some eruption, or of eruption without elevation, and to the intimate connection existing between them.

CHAPTER VII.

BOTANY.

(1.) *Characteristics of the Lower Zones of Plants.*

The botany of Teneriffe, as displayed in its several zones of altitude, has been described by so many writers, and at such length, as well as with so great scientific ability by Messrs Barker-Webb and Berthelot, in their grand work on the Canaries, that there are only a few points in the physiognomy of the leading plants, of the region extending from the sea-level to 1200 feet in altitude, that offer any important peculiarities hitherto unnoticed.

These features seem to depend, in no small degree, on the meteorological conditions of the island; and especially on the preponderance of the grand aerial return-current from the Pole, and that action of its 3000 foot stratum of cloud, described in Chapter V., as reflecting back the rays of the sun into the upper region of the atmosphere; thereby lowering the temperature of the coast, and at the same time dropping little or no rain. Situated thus in a constant N.E. wind during summer, and made unduly cold and dry, the vegetation of Teneriffe is not altogether so rich as might have been expected from its low southern latitude.

This effect appears,—*1st*, In the absence of certain plants, such as the Mangrove; *2d*, In the character and small numbers of the species present, as Mesembryanthemum, Euphorbia, Dracæna, &c.; and, *3d*, In the poverty of some of the cultivated forms, as *Phœnix Dactylifera.* This tree, though frequently met with in some parts of the island, is so stunted as to look more like a tree-fern than a palm, and its fruit is seldom perfected; in truth, this plant does not grow so well in Teneriffe, as in latitudes five degrees further from the equator, towards the eastern end of the Mediterranean. But the greatest falling off is in the case of some North American trees, raised with much care in the "Garden of Acclimatation," near Orotava, and viewed with no little pride by the superintendent; because, most probably, he has never witnessed the far higher degree of development which the American climate is capable of imparting to those species of plants.

Although fully aware of the impossibility of arriving at a complete understanding of climate for botanical purposes, except by taking account of many other phenomena besides temperature and rain-fall, yet these being all that I have been able to procure with much completeness, and being by far the most important elements concerned, I

have exhibited some of their chief characteristics in the following table, for New Orleans, Bermuda, Teneriffe, Malta, and the Cape of Good Hope. These places being all at something like the same angular distance from the equator, admit of comparisons and deductions being made with a certain amount of safety; though we could by no means attempt so to do for localities with much greater differences of latitude; for then we should be thrown not only among new species of plants, but should have to consider also certain compensations of nature, of which little is clearly seen except near their culminating parallels.

Name of Place.	Latitude.	Height in Feet.	Distance from Sea-coast in Miles.	Duration of Observations in Years.	Mean Date.	Authority.	Annual Mean Temperature Observed.	Same reduced to Sea-Level, and to Common Latitude 30°.	Semi-Annual Difference.	Same reduced to Common Latitude, 30°.	Annual Mean Humidity, Saturation = 1.	Annual Rain-fall in Feet.	Wind Velocity in Leagues per hour.	Thermal Element.	Luxuriance of untended Vegetation.
	° ′						° Far.	° Far.	° Far.	° Far.					
New Orleans,..	29 57	10	30	20	1844	U. S. Army Meteorological Register, 1855.	69·86	69·86	27·67	27·71	...	5·0	3?	98·	122·
Bermuda, ...	32 19	50?	1?	2	1853	Admiral Fitzroy's Meteorological Papers, 1857.	72·60	74·57	21·50	20·11	...	4·?	4?	93·	93·
Teneriffe, ...	28 25	80	1	1·1	1857	Teneriffe Report, p. 66.	69·68	68·88	16·50	17·34	.69	2·?	5?	87·	50·
Malta, ...	35 54	200	1?	1	1853	Col. James's Abstract of the Rl. Eng. Meteorological Observations, 1855.	67·36	72·69	27·90	23·79	.73	2·3	3?	91·	52·
Cape of Good Hope, ...	33 56	40	2	14	1849	Mr Maclear's Publications at the Royal Observatory, Cape of Good Hope.	61·71	64·54	13·78	12·34	.75	2·0	6	74·	37·
No. of Column.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Referring to the above table, in the first place, for the "Mean Temperatures" in column 7, we may be well surprised to see Malta, though 7° N. of Teneriffe, yet only 2° of Fahrenheit colder; and while New Orleans, though 1° N., is a little warmer—there is something rather startling in finding Bermuda, though 4° N., yet actually 3° of Fahrenheit warmer. And this inflection of the isothermal at Orotava, is made more undoubted still, on reducing all the observed annual mean temperatures to the common latitude of 30°, by the well-known formula

$$T = t \times \frac{\cos 30^\circ}{\cos \text{lat.}}$$

These quantities, corrected also for the height of the stations above the sea-level,

are given in column 8; where, if the islands east and west of the Canaries are so much hotter, yet New Orleans is not very different. Why, then, the poverty remarked amongst the American trees in the "Garden of Acclimatation," near Orotava? The answer is, that luxuriance of vegetation does not depend, in its thermal element, so much upon mean annual temperature, nor yet even on mean summer temperature, as on a combination of the former with the elevation of the latter above winter temperature, modified probably by distance from the Equator. Now this quantity, —the "semi-annual difference,"—as deduced by subtracting the mean temperature of the coldest month from the same for the hottest month, is given in column 9 as observed, and in column 10 as reduced to 30° latitude; and therein we immediately behold the deficiency of the Teneriffe climate. It is indeed, in this characteristic,—the "semi-annual difference,"—more unlike the American climate than any other place we have returns for in the Northern Hemisphere; and no amount of irrigation —which in a hot country is too often supposed capable of doing anything and everything, and is very liberally supplied in the Orotava garden—can ever make up for the Canarian winter being warmer, and its summer colder, than that of New Orleans.

While this amount of drawback must always prevail in Teneriffe amongst cultivated plants,—and is indicated by decrease of the numbers in column 14, or the sum of the annual mean temperatures, and, the "semi-annual differences reduced,"—there is a much greater proportion still, to be set down for the uncultivated or natural vegetation; for that will be further affected, *positively*, by the "Humidity," and still more so by the rain-fall, given in column 12, but *negatively*, by the amount of wind, as suspected rather than observed, in column 13.

No one who has seen on trees, at the Cape of Good Hope, the withering effects of continual trade-wind gales, will doubt the importance of this element; but even in some of our best observatories, as well as with amateurs generally, there is still such a strangely primitive method of registering wind by the feelings,—or if, as rarely done, with instruments, those giving instantaneous pressure only at the moment of observation, instead of such as register the whole motion of the air over a spot, for any given period of time, long or short,—that I have thought it better, in the present incomparable state of returns, altogether to omit introducing the effect of this agency.

Those of rain are, however, far more certain; and after a practical experience of several years in cultivating under a latitude of 34°, I have little hesitation in multiplying the thermal element, by the rain-fall in feet divided by 4, as with the numbers of column 15. These accordingly express, with some approximation I hope, the natural luxuriance of vegetation in each country, and, not impossibly, the unhealthiness of its climate; making the difference between New Orleans, and Orotava, wider than ever; and completely compensating the latter, for the poverty of its imported Magnolias, by indicating for its climate a surpassing degree of healthiness.

Thus far, no allusion has been made to the last line of returns, or, for the Cape of Good Hope, but they are of the utmost value; *firstly*, as indicating, by their remarkably

small "semi-annual difference,"—that the climate of a place, on the borders at least of a large continent, may, from local causes, be more insular than that of most islands themselves, and in the very feature usually thought most typical; *secondly*, as bringing to light, if not the healthiest spot in the whole world, at least one far healthier than the Northern hemisphere has to show (see column 15); thereby fully bearing out the surprisingly small mortality amongst British troops, when stationed in that part of South Africa.

These Cape meteorological returns, are in fact so extraordinarily favourable, that some slight suspicions of their correctness can only be dissipated, and are then entirely destroyed, by examination of, and enquiry into, the particulars of the numerous and careful observations for fourteen years, by a first rate scientific man, on which they depend. In fact, there can be no doubt but that Mr MACLEAR's numbers represent the climate of the Cape Observatory with extreme accuracy. There is, however, still the question, how far the site of that building resembles the circumstances of the Cape Colony at large, or any considerable portion of it; and there are doubts amongst those who have been there, whether, placed as it is in the deflected and concentrated blast of the S. wind, sweeping past Devil's Berg—the Observatory has not a happy means of moderating summer heat, confined to a few favoured yards of ground. Certainly were the establishment taken from its present site, and placed where Professor HENDERSON had wished it, on Wynberg Hill, there would have been a marked climatic difference to note; and a considerable approximation to the circumstances of Orotava, as regards bearing of sun, and dominant mountain. Doubtless, neither one locality nor the other would give a perfect return for the whole country; and perhaps no meteorological observatory should be considered capable of furnishing standard results, until it has connected itself meteorologically with many points in the surrounding country, by the same sort of survey, *mutatis mutandis*, that is found so necessary with magnetical stations. Meanwhile, however, taking the numbers as they stand—the Cape climate is proved to be cool beyond all comparison for its latitude; and evidently owes that coolness, not to cloudy skies, for they are remarkably clear, but to the continued wind; for this sweeps away, bodily with the air, all heat reflected or radiated from the ground, as fast almost as generated under a nearly vertical sun.

When coolness near the tropics arises from such a cause, the local atmosphere must be pre-eminently luminous; cheering and invigorating to man, but trying and overpowering to plants, which, then, either retreat, like so many of the Cape flowers, into their subterranean bulbs during summer, or encase themselves, when arid air also compels, in the antivaporizing skin of succulent leaves.

Judging from the comparative abundance of these two classes of plants, and making some allowance for qualities of soil, there appeared to us, in the littoral regions of Teneriffe, to be fewer bulbs, and more succulent forms, than at the Cape; or, in other words, the plants spoke of a climate with less radiation, but more dryness, than our

southern colony. Less *radiation* can excite little surprise, for the Cape, with its clear sky and wind-purged atmosphere, must be near the earth's maximum in this respect; while, if we follow the S.E. wind from Table Bay down to latitude 28°, as in sailing to St Helena, we actually do come under a much cloudier portion of the Southern Trades; under something, in fact, which would decrease the radiation there, just as the great sea-cloud of N. latitude 28° (see p. 488) effectually decreases the radiation about Teneriffe. Greater *dryness*, however, would hardly have been expected amongst those who know the very high standing of the Cape atmosphere in that respect also. But thirteen months of Mr KREITZ's observations, giving ·687 for the humidity (even of Orotava, which, reduced to Santa Cruz anchorage, see p. 521, and the coast generally, should perhaps be ·650), while Mr MACLEAR's results for the Cape give ·751,—leave no doubt of the fact; and this fact seems to throw a curious illustration on the old Guanche custom of allowing, or rather in their being enabled to allow, their dead to dry up into mummies in caves on the mountain side.

(2.) *The Higher Zones of Vegetation.*

In any ascent or descent of Teneriffe, the characteristics of an island flora, in poverty of species as to number, has a remarkable effect in simplifying the problem of hypsometric distribution.

Thus, on August 25th, descending from Alta Vista, above what may be termed all practical vegetation,—*i.e.*, above everything but an occasional lichen, or some little plant growing in an exceptional corner,—we entered the upper limit of the Retama (*Cytisus nubigenus; Spartium nubigenum* of Von BUCH), at 9800 feet of altitude. From that moment, and for half the day, while toiling through the basin of the Great Crater, we saw practically nothing but the isolated Retama bushes. We reached the Canadas, ascended the crater-wall, passed down the northern slope, and still found nothing but Retamas. On and on we went, Retamas and nothing but Retamas on both sides. Suddenly, at 5700 feet of altitude, a new plant was seen, of a bright yellow-green colour, but stunted and growing like a creeper amongst the stones. In a minute after, several more of these bright green plants were seen, and began to look like Heaths. In three minutes more, there was nothing but Heaths about; four minutes of a mule's slow walking, had sufficed to convey us from a world of nothing but Retamas, to another as entirely devoted to Heaths (*Erica arborea*).

The elevation limits of the plants, however, appear to be much affected by soil. On the journey just mentioned, the route lay along the sloping back of Mount Tigayga, covered with deep and loamy earth, the remarkable "Tosca" stratum, well particularized by Von BUCH. This appeared equally suitable to Retama and Heath, and their hypsometric qualities alone divided them; the former extending from 9800 to 5700 feet of altitude; and the latter from 5700 to 1800 feet, but in the course of that space having its empire interfered with by many new plants.

In the *ascent*, on the other hand, by the valley of Taoro, the ground was mostly

rocky; the Heaths were poorer, and extended up only to 4900 feet; while covering their omission, as it were, from 4900 to 5700 feet, another plant, that had not been seen at all on Tigayga, (and here had appeared first at 4200 feet, the *Adenocarpus frankenioides* or "Codeso"), multiplied and extended up to, and mixed with, the Retama at 6000 feet and upwards. From 5700 to 5900 feet we had the curious lateral arrangement, that on the rocky slope we were ascending, was nothing but "Codeso;" while on the loose cinder heap on our left, from which we were only separated by a narrow but deep ravine, was nothing but "Retama." After once having entered the basin of the Great Crater, with its loose pumice, the Codeso disappeared; but on arriving at the external slope of Mount Guajara, the plant reappeared on that rocky, though friable soil, in a stunted form; and, together with the Retama, which had lasted the whole of the time, reached a height of 8900 feet.

Ferns were found from 2300 to 5400 feet; a splendid hypericum (*Androsæmum Webbianum*), with its bright yellow flowers and pink young leaves, from 1400 to 4900 feet; Laurels from 3500 to 5000 feet; and Grasses from 2300 to 3700 feet of elevation.

This last measure goes so directly against the hypsometric arrangement of vegetation on Teneriffe, by the greatest traveller of the age,—who emphatically makes the highest "zone" to be that of the "Grasses," and who even describes how, near to Estancia de los Ingleses, 9700 feet in altitude, he had to lean backward in order to avoid falling on the slippery surface of "the compact short-swarded turf" (see Baron HUMBOLDT's 'Personal Narrative'),—that a few words upon it may not be out of place.

The Zone of Grasses is evidently a most important one to have properly fixed; for it at once implies the accompanying climate, viz.,—frequent moisture, clouded sun, and moderate temperature. Now, these are only to be found on Teneriffe during the summer, at about a level of 3000 feet, or precisely where we met with grass in luxuriant abundance; but above that level, and the whole way up to the top of the mountain, the soil was terrifically dry; and with good reason, when the dew-point depression (see pp. 517 and 518) was greater by day, and by night, than in the African desert, and the unclouded sun shone with a burning quality of radiation, that must soon have killed any tender herbage; while at the height and very place of the alleged short-swarded turf, we found, and the photographs represent, only, naked blocks of lava, or rolling fragments of glassy, unoxidated pumice.

In the winter time undoubtedly there is moisture on the upper part of the Peak, but it is in the shape of snow, under which vegetation is dormant; and though it might be expected, that when, in early spring, the arid air and burning sun resume their reign, the appearance of some peculiar and ephemeral plants might follow the retreating snows,—we saw no trace of them in July; and they are probably few, by means of the sudden manner in which the deadness of winter, passes into the brightness of summer, at great elevations.

The living and growing period, then, about 9000 feet of altitude more or less, is only during summer, whose climate is characterized by drought and radiation; and, under such circumstances, we need not wonder at finding the only candidates for constituting the upper vegetable zone in Teneriffe, to be bushes of the *Cytisus nubigenus*, with hard woody stems, and exceeding long roots, admirably adapted to enable the plants to fix themselves in the slopes of loose volcanic ashes, and to resist and profit by the intense glare, and stimulating effect, of a mountain sun and dry cloudless atmosphere.

Were the Peak high enough to enter the summer level of S.W. clouds, its top might then present a growth of grass, as does the plain of Desaguadero in Peru at a height of 15,000 feet; but it is not high enough by several thousand feet, and is thence compelled, at that season, to offer to botanical geographers, on one hand, an intense example of the zone of dryness that occurs in the atmosphere between the two cloud levels, or from 4000 to 14,000 feet of altitude; and to astronomers, on the other hand, a station elevated high in the atmosphere, without any accompaniment of mist or rain, or even dew.

(3.) *Geographical Zones of Plants.*

The variation of plants from the base to the summit of a mountain, has often been compared to that which is found at the sea-level, when proceeding from the Equator to the Pole. The mountain scheme we have, however, found to be imperfect by reason of the omission of effects of dryness and radiation; and something of the same sort appears to have occurred with the geographical theory. Thus, in the authorised translation of COSMOS, vol. ii., p. 88, we read,—" When rising from local phenomena we embrace all nature in one view, we perceive the increase of warmth from the Poles to the Equator accompanied by the gradual advance of organic vigour and luxuriance. From Northern Europe to the beautiful coasts of the Mediterranean, this advance is even less than from the Iberian peninsula, Southern Italy, and Greece, to the Tropical Zone. The carpet of flowers and of verdure spread over our bare and naked earth is unequally woven—thicker where the sun rises high in a sky either of a deep azure purity, or veiled with light semi-transparent clouds; and thinner towards the gloomy north, where returning frosts are often fatal to the opening buds of spring, or destroy the ripening fruits of autumn."

In this eloquent passage, temperature is alone looked to; and with its increase, so is thought to be the richness of vegetation. Yet a moment's consideration will show, that heat alone would infallibly destroy a plant; and a cursory examination of the actual distribution of plants over the whole earth, would prove,—that precisely in the latitude where the increase of vegetation is said to be most marked, or between the temperate zones with their grass and oak trees, and the tropics with their palms and reeds, there is a well marked, and broad, belt of decrease, and almost entire disappearance, of vegetation. This belt, though with many breaks from local causes, is

sufficiently marked in either hemisphere, as witness Arabia and Sahara in one, Pampas, South Africa, and Australia in the other; and coincides in latitude with the rainless region of the trade-winds at sea—winds that, coming from the cold of the Pole, and moving daily to a warmer latitude, have their capacity for moisture continually augmenting; cannot be felt as anything but very arid currents; and when blowing over such land as the deserts of North and South Africa, heated daily by a high and cloudless sun, must produce the sterility which is found.

When, therefore, in the plains of Latakoo, 27° from the Equator, Mr BURCHELL describes the only vegetation as consisting of small scanty plants, thinly dotting the otherwise bare and desert soil, and each of them, though not two feet high, as yet endued with a hard woody stem, in appearance like a miniature tree, and with an age perhaps of two or three centuries,—he is recording the rule, and not the exception, of lands within trade-wind influences; and is giving the details of a slowness of vegetable growth, combined with an inclination to hard wood rather than to grassy herbage, which bear a striking resemblance to what is found on Teneriffe at a height of 9000 feet.

The intervention of a fall of rain from an upper current of the atmosphere, or the occurrence of a spring fed from a distant mountain, will doubtless produce in those subtropical deserts, in one case a sudden brightening of vegetation, and in the other the grateful appearance of a green oasis,—yet the peculiar and manifold influences of aerial drought are visible still; and being constantly present, produce far greater effect in modifying flora, than many inches in depth of rain; for that may, and in those countries generally does, fall nearly altogether in one heavy thunder-shower, floods the country for a few hours, and then leaves it once more to long weary months of scorching blaze of sun by day, and the gnawing of arid air by night.

Abandoning, therefore, the rain-guage, in favour of those exact and absolute Hygrometers with which our worthy countrymen, MASON and DANIELL, have lately armed mankind, let us inquire what is their instrumental expression for the mean annual aerial dryness of various countries arranged in order of latitude. For this purpose, referring again to Colonel JAMES' Meteorological Extracts, on account of the closely comparable character of the Royal Engineer returns, and adding to them Mr AIRY's determination for Greenwich, and Mr KREITZ's for Teneriffe, we have the following succinct numerical view of a zone of dryness intermediate between the equatorial and temperate bands of moisture, so very clearly marked, as to be well worthy the careful consideration of botanists, when laying down their "climatal zones" for plants, or defining "phyto-geographic regions:—"

Name of Place.	Latitude.	Mean Annual Humidity.
Ceylon, ...	7°	·823
Barbadoes and Jamaica, .	16	·767
Teneriffe, ...	28	·687
Malta and Gibraltar, . .	36	·740
Halifax and Newfoundland, .	46	·814
Greenwich, ...	51	·852
Edinburgh	56	·812

(4.) *Dracæna Draco, the Dragon-Tree.*

Dracæna Draco is a plant so remarkably typical of Teneriffe, as an African island, in the zone of intense drought, and light, with moderate heat, existing between the tropics and temperate latitudes, that we made it a special object of photography from the age of 3 years—when it is to common observation much like a Yucca or some of the smaller Agaves,—to its arborescent condition at the ages of 20, 70, 100, and, if accounts are to be believed, up to 6000 years in the case of the "Great "Dragon tree" of Villa Orotava, now enclosed by the garden of, and cared for most exemplarily by, the Marquis of Sauzal. (See Photographs, Nos. 61–71.)

At 20 to 30 years of age, the continual lengthening of its stem makes a Dracæna Draco somewhat resemble a sturdy young palm-tree—its crown of radiating, sword-shaped leaves being often 2 to 3 feet long. After this age the stem branches at the top, and the appearance is rather that of a family cluster of little palm-trees, growing on a common stock; while in the very aged example above alluded to, its branching has been repeated several times.

With this deviation from the growth of a palm, a most unexpected one has taken place in the trunk; for, seeing that it is endogenous, no increase of its diameter ought to be found, yet from 6 inches it has grown to 12 feet. How is this? On examining many younger specimens, and finding that as long as the stem was single, it was smooth, or marked only by transverse wrinkles, the impression of old footstalks; but that from the moment of branching, it began below that point to be corrugated longitudinally, and that these corrugations divided as they descended,—we were induced to look on the branches as so many young trees, and the corrugations as their roots inosculating with each other, and with the bark of the original stem, whose life has ceased, and on whose top a number of new trees are now growing.

On visiting the old patriarch of Villa Orotava, this idea was confirmed,—1*st*, By the smoothness of every one of its smaller stems, from the leafage downwards to the first fork, where the longitudinal markings began; accompanied there by a few effete, dangling radicles, that, seeming to have failed in inosculating with the bark, had shrunk and withered; 2*d*, By the utter hollowness of the interior of the tree; and, 3*d*, By the general pyramidal form of the trunk outside. In connec-

tion with this feature, it may be remarked, that some of the Pandanus tribe are known, as the tree grows tall and top-heavy, to send out roots from a few feet above the ground, at an angle of 15 to 20 degrees; these roots are, therefore, admirably contrived and fashioned to become buttresses to the vegetable pillar. If the Pandanus in old age needs this additional support, much more does Dracæna Draco, carrying, as it were, a host of such trees on its back. What, then, is the shape of the ragged envelope of inosculating roots forming the apparent trunk of the huge endogen of Orotava? Measurement being applied (by putting a rope round the tree, and taking the best average we could of still standing portions of its circumference, with their large holes, and breaks partly filled in with masonry), gave us in 1856, 48·5 feet of circumference at the level of the ground, on the southern side, (on the northern it descends 5 feet to a lower level of the garden), 35·6 feet at 6 feet high, and 23·8 feet at 14·5 feet high, or close under the first branching. Putting these numbers together, they give the form of a truncated cone, having an angle of 32 degrees; a form, in fact, admirably suited for a buttress against winds from every quarter, and characteristically expressed in Photograph, No. 68, Vol. X.

Although instructed lately by my friend, Professor Balfour, that this idea of the Dracæna's trunk being formed of roots, is not new, having been arrived at by M. Gaudichaud and M. Petit Thouars from their researches in structural botany,—yet, as their view is not generally adopted, and has been even pointedly opposed by MM. Mirbel and Trecul, it may not be altogether useless to detail, as above, an induction formed, without theoretical prejudice, at the time of viewing the actual facts; and a conclusion which seemed on the ground, to the eye of an ordinary observer, to reconcile all the phenomena of the most extreme case that is known, though they appeared at first to be eminently and strikingly anomalous.

Age of the Great Dragon-tree.

The great "Dragon-tree" has the repute of being the oldest, though by no means the largest, tree in the world; and to number, perhaps, 5000 or 6000 years. In the last 70 years, comparing our measure of the circumference in 1856 with Borda's, there has been no sensible increase; indeed, rather a decrease. Of late, then, its growth must have been indefinitely slow; but whether it was always thus, is not a matter to be scientifically ascertained by present examination, for not only is the tree endogenous, therefore presenting no annual rings, but the trunk is quite hollow; and while a large part of the casing was cruelly hacked away a few years ago for transportation to Botanical Museums in Europe; the remaining portion, judging by present appearances carried on to future time by aid of the physiological theory already given, is gradually subdividing, and becoming each year more manifestly the mere circle of roots that it is.

Nothing certain, then, can be said either way; the tree may be 6000 years old, and may be very much less. The advocates for the higher antiquity should, however, be

cautioned, that Dracæna Draco does not in its youth grow so very slowly as often represented. Of this they may judge by the ages assigned to three of the trees in the Photographs in Vol. X.; two of which depend on a letter addressed to me, when on the Peak, by Mr DISTON, an eminent English merchant in Orotava. His letter is so clear and precise that I give it here verbatim, and have only to add, that the trees therein mentioned, are of the height of about 15 and 23 feet respectively.

" OROTAVA, *30th August* 1856.

" MY DEAR SIR,—My son ALFRED tells me that you expressed a wish to ascertain the ages of the dragon-trees you were photographing yesterday; and I am glad it is in my power to give you a very proximate account of that of two of them, as, until eight years ago, the estate they stand on belonged to the firm I was connected with, and I consequently know every foot of the ground, and every plant that was upon it previous to that time.

" The small dragon-tree you first acted upon was planted by myself in the year 1833; it was then about 20 inches high, and I presume must have been about 3 years old when I obtained it.

" The other tall one (in the cross walk), was planted in 1818, at about the same size as the one just spoken of. For a long period I used to go on removing the undermost leaves, and thereby increased the development of the trunk until it became too high for me to reach its head conveniently without a ladder. Yours very truly,

(Signed) " ALFRED DISTON."

Country of the Dragon-tree.

On the known size of " the Great Dragon-tree," its presumed age of many thousand years, and an assertion that its original country is the East Indies, one of the greatest botanists and physicists of the present age has inferred, that the Guanches of Teneriffe must have been a commercial and voyaging people, in times of very high antiquity indeed. For if the tree be, in truth, nearly 6000 years old, and grew, in its first 40 years, to as great a height as Mr DISTON's specimen just described, its transportation from the East Indies to the Canaries must have occurred more than 5000 years ago; and could not well have been effected, without the arts of ship-building and navigation being in a high state of excellence at that distant epoch. Yet when the Guanches were discovered by the Spaniards four centuries ago, they were a simple pastoral people, without any knowledge of iron, and using fragments of obsidian for their cutting instruments.

The conclusion, therefore, drawn from this botanical testimony is something not a little dazzling and wondrous, as well as quite unexpected from the tenor of every other species of reliable evidence. It must, however, be consented to, if the very important assertion quoted be correct, viz.,—that " India is the true, and only, natural country of the tree." On this statement, indeed, the whole argument turns;

and such is the weight deservedly attached to every utterance of the great HUMBOLDT in his immortal "Personal Narrative," that the simple words have, nearly everywhere, been received as fact.

Some persons have certainly of late attempted to raise the objection, that Von BUCH, having discovered Dracænas growing wild near Igueste in Teneriffe, and also in Madeira, involuntarily demonstrated thereby that the tree was indigenous in those islands; but inasmuch as the plants he saw, must, from their small size, have been very much younger than the wondrous patriarch of Orotava, it is quite within the limits of possibility that they were the produce of the latter's seeds, spread by winds, birds, and man, in a climate and soil suitable to their growth. Those mere juveniles, therefore, can by no means be held to throw much light, far less to decide incontrovertibly, on whether their aged parent was brought to its present locality by nature or by man, for in either case, granting that it flourished, flowered, and produced seed, as indeed it is still doing, propagation of its species would equally follow; and there are known instances of plants transported by man, spreading faster than the native vegetation; as with the remarkable development of Spanish thistles in the Pampas of Buenos Ayres.

Yet though the objection raised is confessedly weak, the conclusion deduced may, after all, be perfectly correct; for when we come to inquire into the scientific or historical reasons for believing India to constitute the true and original country of Dracæna Draco, it is with great difficulty that we find anything but negative evidence; and we are then thrown back on the simple question, of which country possesses the oldest examples of this giant of the Liliaceæ.

Now, the immense age of the Orotava specimen being generally allowed, and having become quite proverbial, we have merely to ascertain if India has any Dragon trees which can at all compete with it. An examination instituted to this end has shown that, though Dracæna Draco does exist in that country, the specimens are rare and poor; and I have been assured by a scientific officer of the Hon. E.I.C., (Lieut. A. AYTOUN, B.A., who enjoyed during several seasons an unusual amount of opportunity for exploring the Bombay Presidency in different directions, in the course of Geological employment), that he had never been able to meet with any instance of the plant, to which a greater age, than two and a-half centuries, was attached by the natives; and they looked on it as an imported tree, introduced on account of its medicinal gum,—the "*Sanguis Draconis*" of the old Pharmacopeias.

These circumstances must be allowed to be of no small importance in determining the case; for remembering how various Western plants, as maize and potatoes, have been carried eastward in modern times, and successfully introduced into, and spread over, Hindostan,—what is more likely than that the Portuguese, during the brilliant period of their Indian empire, conveyed to its insalubrious shores from Madeira or Canary, a plant so highly thought of by the physicians of the period, as *Dracæna Draco*.

This view is much strengthened by a discovery lately made by Dr JOHN BALFOUR, H.E.I.C.S., detailed in a paper read by Dr Douglas Maclagan, before the Botanical Society of Edinburgh in May 1857; and to the effect of finding an American medicinal tree, *Thevetia nereifolia*, Juss., or *Cerbera Peruviana*, Math., growing wild in a jungle of the Bombay Presidency, but under circumstances that proved beyond all doubt that it had been imported by Europeans.

Published Views of the Great Dragon-Tree.

An observer's account of "the Great Dragon-Tree" could hardly be concluded, without some reference to its numerous published portraits. One of the latest of these is in Professor MACGILLIVRAY's Account of Baron HUMBOLDT's Travels, and represents the tree with an immense solid trunk, branching majestically towards its summit, and abundantly covered with masses of small-leafed foliage, something like an elm; it is standing in flat bare ground, and, measured by the height of the man going up the ladder, is 150 feet high,—more than double its true height, or 66 feet above the ground on the north, and 61 feet above that on the south.

Had MACGILLIVRAY drawn from nature, he could not have erred thus widely in every important scientific feature and pictorial accompaniment; but he had copied HUMBOLDT's plate in the 'Atlas Pittoresque,' and that, through the medium of M. MARCHAIS, was copied from a sketch by M. OZONE, the artist who accompanied the Chevalier DE BORDA to Teneriffe towards the end of last century.

Photographs from OZONE, HUMBOLDT, and MACGILLIVRAY are given in Vol. X., pp. 40, 41. Compared with the tree itself on page 37, they show the immense debt which the scientific world owes to the inventors of photography, not only in replacing the artist's original sketch, but also in performing the subsequent copyings: for induction from the facts clearly demonstrates, that even in the simplest feature, man following his fellow-man, diverges inevitably at every step further and further from truth as it is in nature. Thus, not only does the tree in each succeeding copy rise to a greater height than before, its foliage become more abundant and conformable to European types, its trunk more ligneous and solid, and the ground round about more flat and open,—but a mere bit of gardener's scaffolding, that supports a bending branch on one side of the tree, and has nine cross bars to permit vines to clamber up,—is transformed by OZONE into a ladder with 14 rounds, increased to 28 by HUMBOLDT, and to 32 by MACGILLIVRAY, each of them professing all the time to give a faithful reproduction of his predecessor's picture.

Continued copying on this principle was evidently so hopeless of benefit to science, that all thanks are due to Mr WILLIAMS, who, in BARKER-WEBB and BERTHELOT's magnificent work, has produced a new original,—not perfect, as what human work can be,—but, like every fresh examination of nature, it has some portions of truth which had previously escaped recognition. Accordingly, in Mr WILLIAM's sketch, there is an excellent representation of the true leafage, the abortive rootlets of the

smaller branchings, the pyramidal form of the trunk, and its longitudinal corrugations,—as he saw them in 1830; but when even he would exhibit historically the appearance of the tree as it was in 1790, he puts the massive and erroneous foliage of OZONE on his own correcter trunk, the shape of which he appears to have well observed, and had confidence in as a botanist.

Full justice, however, to the formal and almost architectural beauty of this pentacrinite-like tree, will probably never be done, save by some native artist still to arise; for a European visitor is too much astonished at first sight, by the Dracæna's extremity of difference from all the trees he has been accustomed to from his childhood upwards, to feel æsthetically with the new and most strange-looking object before him; and his stay in the island is usually far too short for enabling him to overcome the prejudices of his earlier years. Hence depreciating expressions, indifference, and neglect. Yet there is, it cannot be doubted, a wealth of subject, and beauty of a new and a noble order, in both the Dracænas and Euphorbias of this unique climate; a beauty, too, of which little is possessed by the more showy and abundant, but far less symetrical flowers of the steaming tropics; and which is, perhaps, more suggestive in some lines of thought to the poet, the painter, and the decorator, than the productions of any other climate under the sun.

For some purposes hothouses and botanical gardens may answer well, but not for bringing us acquainted with the artistical characteristics of plants from the luminous juxta-tropical zone. All the ingenuity of man is so utterly unable to supply plants with artificial light in any appreciable quantity, though heat and moisture may be furnished with the utmost extravagance, that if we desire to see what light can do in modifying vegetable growth, and to witness its highest developments, apart from all constraints and canker of gardening art,—there is nothing for it, but actually to visit those climates and countries, where, as in the Canarian Islands, the happy combinations of a high meridian altitude for the sun, with extreme dryness in the air, unite in affording nature's maximum of atmospheric illumination.

CHAPTER VIII.

MISCELLANEOUS OBSERVATIONS.

(1.) *Atmospheric Dust.*

With a view to ascertaining the constituents of that remarkable dust-haze so often observed in the higher atmosphere at Guajara (see pp. 481 and 482), and bearing in mind Professor EHRENBERG's statements of the South American origin of dust-showers in the Canarian seas, I had a modification of a rain-guage constructed as a "dust-catcher," and exposed it on the roof of our mountain meteorological house. The instrument, however, proved unsatisfactory, from being so often filled with sand, manifestly raised up from the ground close to us, by the little whirlwinds so common at that height.

A very decided case, however, of a fall of atmospheric dust all over the Canarian Islands, had occurred about a month before we arrived; and Mr CHARLES SMITH of Orotava kindly gave me nearly half an ounce of it, which he had brushed off the leaves of plants at the time.

Not long after, too, SAMUEL R. SWANN, Esq., assistant-surgeon of the United States Frigate "James Town," then lying in Santa Cruz Roads, very obligingly furnished me with a small glass-stoppered bottle, half filled with an atmospheric dust. This had fallen on his ship during the 9th, 10th, 11th, 12th, and 13th of February 1856, between latitudes 7° 17′, and 8° 20′ N., and longitudes 13° 19′ to 17° 43′ W. This specimen he further accompanied by copies of the frigate's "Abstract Log" for those days, with most commendable fulness of meteorological particulars from hour to hour.

Thence it would appear, that the ship was surrounded during that period by a "dust-fog," during which there was a constant precipitation of fine, ipecacuanha-coloured powder on sails, ropes, and deck. The wind at the time was northerly, varying from N. by W. to N. by E., but very light, and considered by the sailors not to be the "Trades," which they describe entering a few days afterwards.

On returning to England, and submitting both these specimens of dust (the Canarian and the sea) to examination with a microscope armed with a magnifying power of 400 linear, hardly anything could be made out but particles of sand. As Dr KINGSLEY, who kindly assisted in the search, with his well-known enthusiasm and microscopic skill, remarked,—" One specimen differed from the other only in the

larger size of its grains." The sea-dust varied from ·00006 to ·00019 inch; and the Canarian, rising from the same size, occasionally reached a diameter of ·0027 inch; but tended rather to a general size of ·0017 inch in diameter.

The colour of either was mostly an ochry yellow, with an occasional bright red, more rarely a green fragment; but nothing organic could be clearly distinguished of a diatomaceous character; the forms of almost all the particles being like quartz rocks in miniature.

Within the last few days I have submitted a remnant of the produce of the Guajara dust-catcher to the microscope, and though the greater part was only coarse sand, yet a finer quality was found adhering to the sides of the lower capsule, with diameters as small as the sea-dust; and exhibiting undoubted organic forms in a broken condition. These at first gave rise to great hopes; but were soon made out to be scales from butterflies wings; and although one felt rather taken by surprise, on suddenly finding this minute testimony, to the existence of creatures that had sported for a few days in the sunshine of a previous year,—yet there was not in this anything of a necessarily extra-Canarian character.

(2.) *Corrections of a Barometer at Sea.*

If a marine barometer be held in an inclined position, every one knows that the mercury will, more or less slowly, rise in the tube, as compared with the graduation, until it has attained on the incline the same vertical height which it had before. Now, any oscillation in such a barometer, as when it is hung and swinging like a pendulum in gymbals, or rolling like a ship, will be on the whole, in its effect on the apparent height of the mercury, equivalent to a certain mean inclination; and the action of any suspended weight at sea, we ascertained on the voyage by actual observation, to be not only as compared with the ship, but with absolute position also, a constant oscillation or angular movement, smaller in amount, but quicker than the rolls of the vessel. With nearly frictionless pivots, this induced oscillation always exists, whenever the ship, or the fixed foundation of the point or points of suspension, is in motion; while if the friction be sufficient to check a sensible portion of such oscillation, then by so much the supported body is made to partake of the ship's rolling.

Hence a naval barometer, as generally hung when in use on a voyage, must always at sea be in a state of more or less oscillation or rolling, either of which movements causes its mercurial column to read apparently too high; and, as the disturbing effect increases with the greater rolling of the vessel, the mercury may appear much too high during a storm. For this reason the sailor has not so clear a token, as he might otherwise have, of a coming hurricane, when, as often occurs, its characteristic cross-sea is met with before the wind is felt; for the depression caused by atmospheric disturbance, is then partly neutralized by the elevating effect of more angular motion in the barometer.

In our voyage home we met with something of a storm, and found, on projecting

the uncorrected barometrical readings, and the same after an empirical correction for oscillation had been applied,—that the representation of a deep atmospheric wave was more notable in the latter case than in the former, as may be seen in the curves prefixed to Vol. IV.

During the occupation of our mountain stations, it was extremely desirable to get at the effect of the rolling of a ship on the height of a barometer on board, because our determinations of heights depended, for their sea-level comparison, on the simultaneous observations taken by Captain Corke in the "Titania," then lying at anchor in Santa Cruz Roads, and rolling considerably and constantly. Under such circumstances it is plain, that the barometer could not have been perfectly steady in its gymbals, or in angular position; there must have been some deviation from the vertical; and consequently, an apparent rise of the mercury in the tube—a correction, in fact, for "rolling" was necessary. The practical plan of getting at it, was to fasten the barometer against the bulk-head in a vertical position when the deck was level, and, having taken a reading, to let it hang freely in its gymbals, and after a few minutes take another reading, which always proved lower than the first, by reason of the angle of oscillation of the barometer in its gymbals being less than the angle of rolling of the vessel. Assuming, as a sufficient approximation in the present state of the question, that the effect of the oscillations was about half of the rolls, the second reading was decreased by the amount of its depression below the first, in order to give what we believed would have been shown, if the vessel had been perfectly steady.

Since returning to Edinburgh, I have experimented on a number of marine barometers of different constructions, attaching them by their gymbal support to an imitation bulk-head, to which a rolling motion could be imparted, similar to that observed on board the yacht; and found the effect always sensible, and generally greater, often much greater, than all the other corrections put together.

(3.) *Elimination of the Angular Motions of a Ship at Sea.*

In the Admiralty 'Manual for Scientific Enquiry,' the deficiency of existing methods of eliminating the effect of the rolling, pitching, &c., of ships from astronomical instruments during observation, having been pointed out—I had applied myself some time since to devise a remedy; and having already arranged an adaptation of the principle of free revolution, and had a specimen made of working size, carrying a small telescope, I was enabled to try it on the voyage to Teneriffe under crucial conditions. The apparatus was found eminently successful, for the horizon of the sea remained bisected in the field of view for several minutes, when the whole rolling of the yacht amounted to as much as 160° per minute.

Frequent observations were made during the voyage, on the manner and amount of these angular movements of the vessel, under varied accompaniments of wind and sea, and have been contributed to the 'Transactions of the Royal Scottish Society of Arts' for 1856–7.

(4.) *Temperature of the Sea.*

Amongst other official instructions for the Teneriffe experiment, is that for measuring the temperature of the sea, on and near the tropic, and, if possible, to $\frac{1}{100}$th of a degree Fahrenheit. I had not, however, any means of going further south than the latitude of Teneriffe.

We did, indeed, observe the temperature of the sea surface daily, on our voyage both out and home; but the results, which are given below, would seem to indicate that at least from 40°, to our Southerly extreme of 28°, N. latitude, the air, season, and other effects may amount to whole degrees; and, in the present state of theory, would render quite misleading any superlative decimal places in a single observation. As they stand, however, these comparatively rude, though I trust, fair measures, may be considered to throw some useful confirmation on those symptoms of an autumnal Canarian current from the S.W., which we had more than suspected from the sea-markings seen at Alta Vista on September 14 (p. 528).

They may also serve another purpose, for on comparing, immediately after they were completed, our "outward" observations with those by Baron Humboldt, upwards of fifty-seven years previously, on almost precisely the same track, and within a few days of the same period of the year, there appeared a small but constant difference, much like a symptom of some secular change in the earth's solar climate; but the moment our "homeward" data were procured, they showed that the anomalous quantity was perfectly explainable as a mere season effect; and that this source of disturbance, even when far removed from any land, is still found in overwhelming amount. The general result, too, of all our sea-observations seemed to indicate that the old idea of the constancy, near the surface, of ocean's temperature must have arisen, not so much from the amount of its annual variation being very greatly less than the atmosphere's, as from the retardation in time of its maxima and minima. Further, that not only must we, in cases where exactness is called for, consider all the changes which occur in the cycle of a year, but those also of the diurnal period, and this even when operating on water many feet below the surface. The subject, however, though difficult, is one, especially in its cosmical bearing, of intense interest, and is well worthy of more special and continued investigation.

Outward voyage in July.		Homeward voyage in October.	
Lat.	Temp.	Lat.	Temp.
°	° F.	°	° F.
38·9	67·5	38·2	68·1
36·9	69·2	35·8	71·6
34·2	69·2	34·0	73·5
31·3	68·5	31·4	74·6
28·5	69·8	30·5	73·8

(5.) *Photographs.*

Having been earnestly enjoined to procure faithful photographic records of various

natural objects in Teneriffe, I worked when there at all spare moments with a simple apparatus procured just before sailing, succeeded in bringing home a number of small negatives on glass plates; and then, with the assistance of a professional printer in Edinburgh, was enabled, in the beginning of 1857, to present the Admiralty with a series of 74 double positive pictures on paper, forming Vol. X. of the MS. Report; besides a few others attached to Vol. VI., and now in possession of the Royal Society. Vol. X. was also presented by the Admiralty to that body, with the subsequent offer from myself, through their Secretary, of assisting in the preparation of enlarged glass negatives, of any subjects that might be selected for illustrating the Report; but after several months, the collection was returned.

Duly bearing in mind the burst of enthusiasm with which the birth of photography was hailed by all scientific men, and the prophetic descriptions that were indulged in by the venerable ARAGO, and a circle of the philosophers of that time, as to the infinite improvement which would, from that day forward, occur to all scientific illustrations; which were, according to them, no longer to be left to the caprice of an artist, but were now to be submitted, "during their formation, to the rules of geometry"—some disappointment must be felt on looking round now; and finding how little has been brought to pass of those magnificent dicta, uttered years ago by great men, to whom the world gave implicit credence.

In spite of such predictions, photography has not taken that special and useful line, on the strength or the hopes of which the French government were moved in 1838: for it is not reforming and supplanting all other methods of illustrating scientific memoirs. Where is the fault or the difficulty? It is not in photography itself; for, as a single specimen of what might have been done in this case, by aid of that most important branch of the art, for which the world is indebted to Mr FOX TALBOT, —my wife has, in the course of a very short space of time, printed off 350 copies of an enlarged negative of one of the Alta Vista photographs, and as many of a stereoscopic view, on a plan suggested by the Rev. BADEN POWELL, of a model of Teneriffe, kindly prepared to our data by JAMES NASMYTH, Esq., C.E.; and they are affixed to pages i. and ult°. of the present edition of this Report.

A more powerful example still, of the perfectly practicable nature of Talbotype photographic illustration, has been offered by the well-known scientific publisher, Mr LOVELL REEVE; for having been applied to, about half-a-year after the official Teneriffe Report had been read in public before the Royal Society, to issue a popular narrative,*—he was so much struck with the amount of important fact, geological and botanical, contained in some of the photographs, that he undertook to introduce twenty of them into an octavo volume; and accomplished it, at the most difficult season of the year,—viz., the depth of winter,—for so large an edition as 2000 copies.

The method adopted in this case, to secure a sufficient number of prints in a reasonably short space of time, and without danger to the original glass, I have described in the Transactions of the Royal Scottish Society of Arts for 1857–58; and it leaves

* "Teneriffe, an Astronomer's Experiment." 8vo. London, Jan. 1858.

nothing to be desired except better "first" negatives than those, which I was only able to procure in 1856, under very untoward circumstances. Vastly better ones indeed might now be taken, by any one going out specially, or even mainly, for that purpose.

The following is a list of the pictures alluded to as forming Vol. X. of the Report, and may give a tolerable idea of the sort of subjects which will meet any future photographer in Teneriffe, as well as indicate the branches of knowledge he may hope to assist :—

No. of Photograph, each a Stereoscopic duplicate.

Volcanic Features of the Sea Coast.

1. Surf and volcanic rocks on the shore of Orotava.
2. View of Orotava looking westward, showing 'volcanic blowing cones' amongst the houses.
3. Volcanic blowing cone in Orotava.
4. Do. do.
5. Do. do.
6. Do. do.
7. Town of Orotava; a parasitic crater, 1000 feet high; the ridge of the Crater of Elevation 7000 feet high; and the Peak or Crater of Eruption, 12,200 feet high.

The Great Crater or Crater of Elevation.

8. Part of the floor of the Great Crater, or Crater of Elevation, as seen from the Peak, showing several small parasitic craters, and many lava streams converging towards the exit formed by the valley of Taoro.
9. Part of the eastern internal wall of the Crater of Elevation as seen from Alta Vista.
10. Mount Guajara, or part of southern internal wall of do. do.
11. S.E. corner of the Crater of Elevation, seen from Guajara; showing the surges of yellow lava thrown out by the central Peak.
12. A cleft through the south wall of the Crater of Elevation as seen from Guajara.
13. The trachyte rock of Mount Guajara; the astronomical station in the distance.
14. Trachyte rock of Guajara.
15. The 'lunar rocks' in the basin of the Crater of Elevation as seen from Guajara.
16. Internal precipice of Guajara, and part of the floor of the Crater of Elevation.
17. A shaken part of the internal precipice of Guajara.
18. A recently broken-up part of the cliff under Guajara, as seen when looking down to the floor of the crater.
19. Close view of fragments of a trachyte cliff.
20. Do. do. do.
21. Trachyte stones on Guajara. The Peak in the distance.
22. Astronomical station at Guajara.
23. Do. do.
24. Do. do.
25. Do. do.
26. Trachyte stones on Guajara.
27. Do. do.
28. Do. do.
29. Table of trachyte on Guajara.
30. The builders of the walls on Guajara.
31. Trachyte wall on Guajara.

The Central Cone or Crater of Eruption.

32. The Peak of Teneriffe, or the cone or crater of eruption, rising in the middle of the Great Crater of Elevation, as seen from Mount Guajara.

No. of Photograph, each a Stereoscopic duplicate.

33. Mount Chajorra, situated on the western slope of the Peak, as seen from Guajara. A stream of red lava is seen below.
34. Crater of Chajorra, 10,000 feet high; as seen from the Peak, 12,200 feet high.
35. Travelled blocks of black stony lava on the smooth pumice-covered soil of Montãna Blanco, 9000 feet high, and on the east of the Peak.
36. Break-down in a glassy obsidian lava stream (the "antepenultimate" class of streams from the Peak) at Alta Vista; altitude 10,000 feet on the Peak.
37. Blocks of stony black lava (the "ultimate" streams of the Peak), rolled from above, and standing on the pumice covering of the obsidian lava below, at Alta Vista.
38. Blocks of stony lava at Alta Vista.
39. Astronomical station at Alta Vista.
40. Do. showing the stream of black stony lava on the north.
41. Alta Vista station, showing the pumice soil and the stream of black stony lava beyond.
42. Alta Vista station, and black stony lava stream to the south. (*This is the view, of whose left hand member the plate on page ult°. is an enlarged photographic copy.*)
43. Culminating point of the Peak as seen from the Malpays immediately above Alta Vista.
44. The Malpays or stony black lava between Alta Vista, 10,700 feet high, and Rambleta, 11,700 feet high.
45. Do. do. do. do.
46. Do. do. do. do.
47. Do. do. do. do.
48. Do. do. do. do.
49. Position of the Ice Cavern in the black stony Malpays, at a height of 11,050 feet. The entrance is close to the figure near the middle of the picture.
50. Entrance to the Ice Cavern.
51. Stratified snow on the floor of the Ice Cavern under the opening of the roof.
52. Interior of the S.W. side of the Crater on the summit of the Peak.
53. Interior of the western side of the Crater at the top of the Peak.
54. Culminating point of the Peak of Teneriffe, being part of the N.E. wall of the Crater on the summit of the Sugar-loaf; height = 12,198 feet.

Plants of the Lowest Zone.

55. *Euphorbia canariensis* in flower.
56. Do. do.
57. Poplar trees on the grand square of Orotava.
58. Terraced gardens above Orotava.
59. Fig trees and Cactus in a garden near Orotava.
60. Banana trees in Orotava.
61. Dragon-trees (*Dracœna Draco*), 3 years old, and a newly formed Cactus plantation.
62. Dragon-tree, 26 years old, and large Cactus plants spotted with the cochineal.
63. Dragon-trees,—the nearer one 41 years old.
64. Dragon-tree of unknown age.
65. The Great Dragon-tree of the Villa Orotava in a garden now belonging to Marquis SAUZAL. The Peak of Teneriffe is just discernible between the two cypresses on the right.
66. The Great Dragon-tree from the south.
67. The Great Dragon-tree from the S.S.E.
68. Trunk of the Great Dragon-tree from the S.E., showing the bottom partly filled with masonry.
69. Trunk of the Great Dragon-tree from the east.
70. Do. do. do.
71. Trunk of the Great Dragon-tree from the south, shewing the extent of decay on that side.
72. The Great Dragon-tree of Orotava as copied by M'GILLIVRAY from HUMBOLDT.
73. The Great Dragon-tree as copied by MARCHAIS, for HUMBOLDT, from OZONE.
74. The Great Dragon-tree as copied by OZONE from Nature.

(6.) *Conclusion.*

Has this Teneriffe experiment, then, served to prove, or disprove, the propriety of Newton's opinion as to the favourable qualities of high mountains for astronomical observatories?

Most eminently, we may answer, to prove it; for how otherwise could so large a harvest of astronomical and general scientific facts, as are indicated in the preceding Report, have been gathered in so short a time; and by a single government servant, limited in the expense he might incur, to one-sixth or one-tenth of what an ordinary expedition usually costs the country! If, too, for more than a century, the suggestive proposition of Britain's greatest philosopher was neglected, because thought impracticable, what an efficient answer can now be returned in the simple statement, that the Admiralty gave their sanction for preparations to be commenced on the 30th of April 1856; and within nine weeks from that date, an astronomical station was successfully established on Mount Guajara, at an elevation of more than 5000 feet above the clouds.

When the whole of the trial had been concluded, and the instruments brought safely home, an eminent French savan, reviewing the entire proceeding, emphatically wrote, that the little expedition which returned to England in October 1856 had inaugurated a new and powerful system of astronomical observation; and he proposed that France should at once follow in the same line, with a station on the Pic du Midi.

France, however, has not yet taken this step; and the working out of Newton's happy idea of mountain astronomy, still remains to Newton's own countrymen.

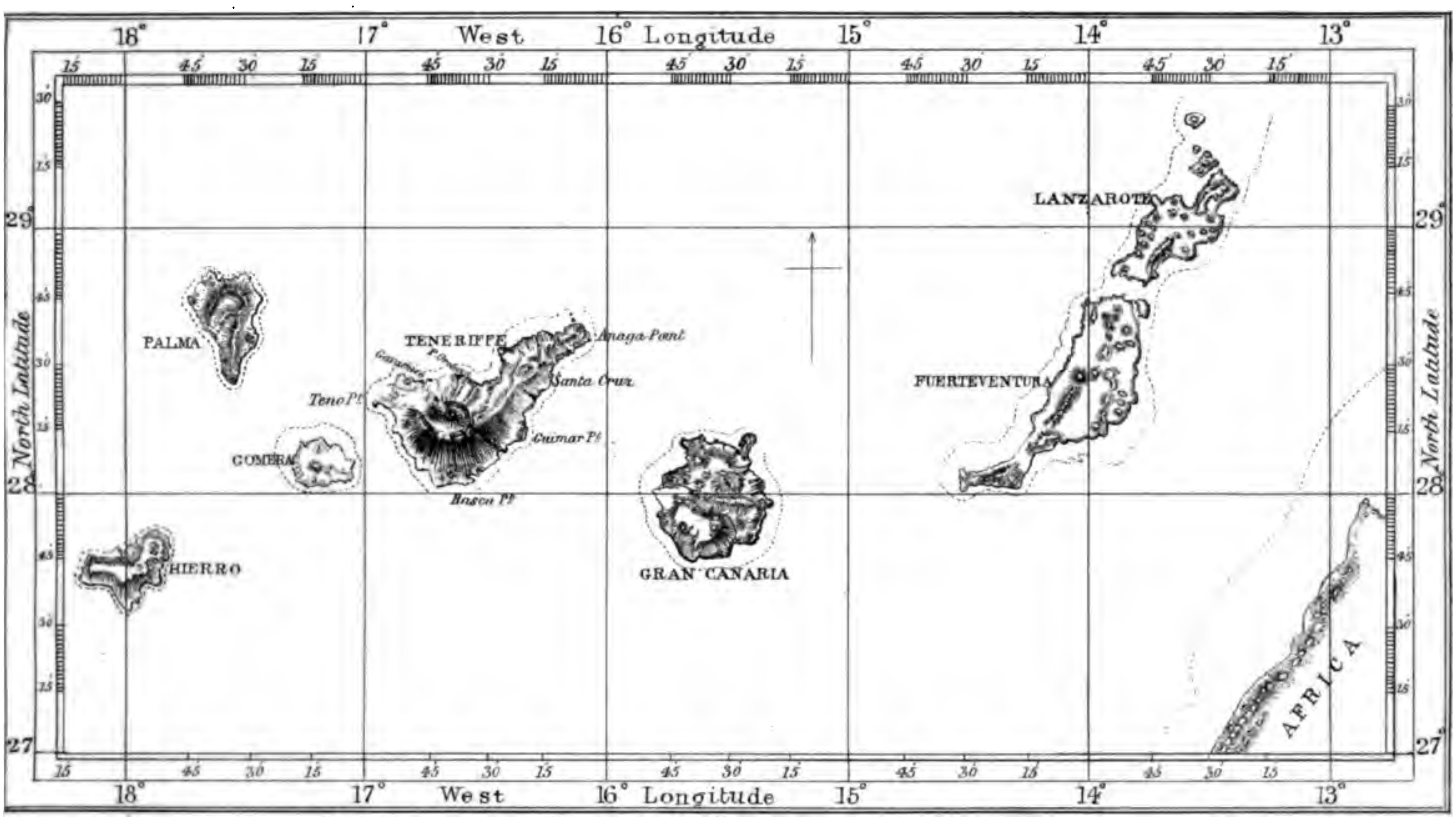
C. P. S.

Edinburgh, 1857.

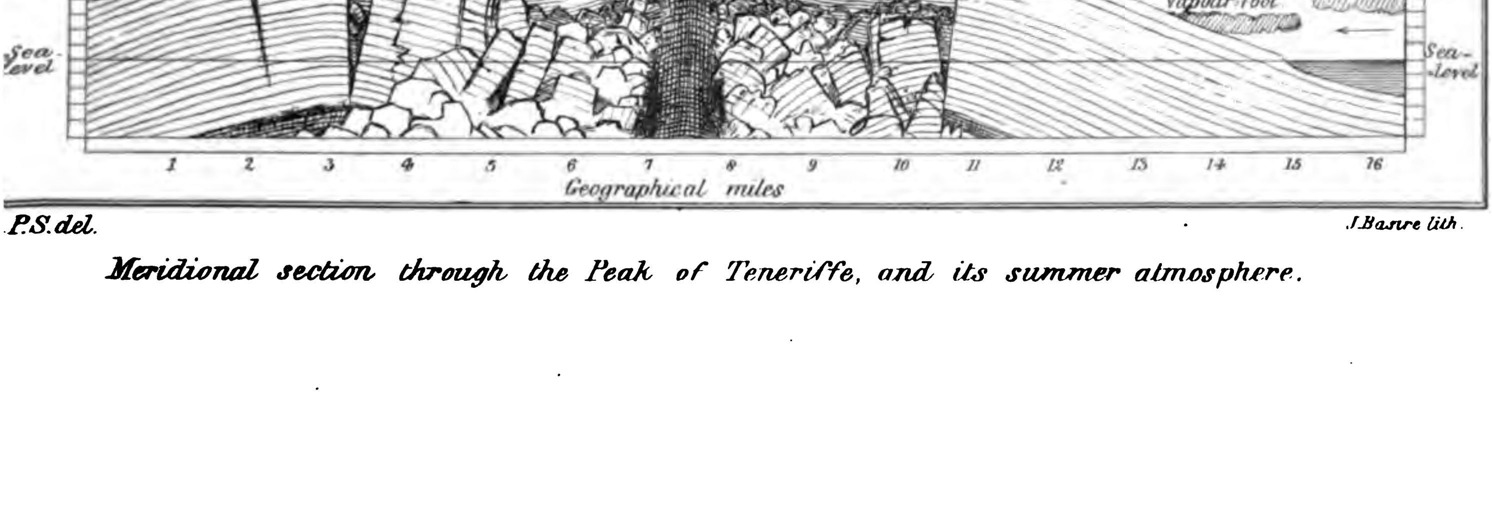
Extract of a Letter received on the 17th of January 1859, from Captain T. G. Montgomerie, B.E., in charge of the Kashmir series of the Great Trigonometrical Survey of India, Col. Waugh, B.E., Surveyor-General:—

"The highest point from which we have taken observations is 19,000 and odd feet. Last year, several of the stations of my survey were over 17,000, and one over 17,900. We have crossed the Great Himalayan Snowy Range in *two* places, by stations on the tops of the peaks."

TENERIFFE ASTRONOMICAL EXPERIMENT.



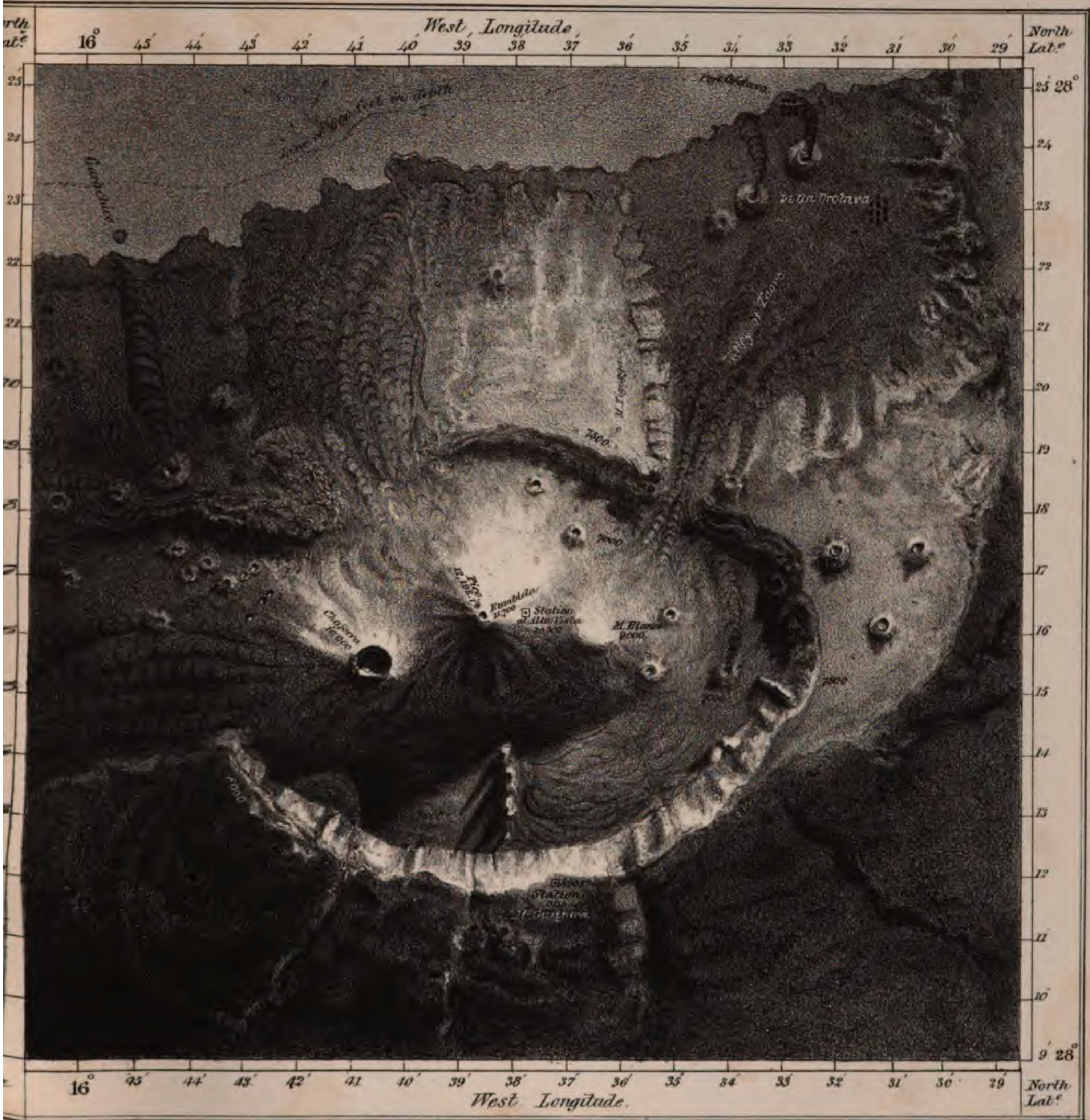
THE CANARY ISLANDS
from the Admiralty Chart
of 1834 & 8,
by Captn. Vidal & Lieut. Arlett R. N.



P.S. del. *J. Basire lith.*

Meridional section through the Peak of Teneriffe, and its summer atmosphere.

TENERIFFE ASTRONOMICAL EXPERIMENT.



PROVISIONAL MAP OF THE PEAK OF TENERIFFE.

Heights in Feet.

Phil. Trans. MDCCCLVIII. Plate XXXII.

The Cloud Horizon Westward from Guajara, shewing the summit of Palma above, and the base of Gomera below the Cloud.

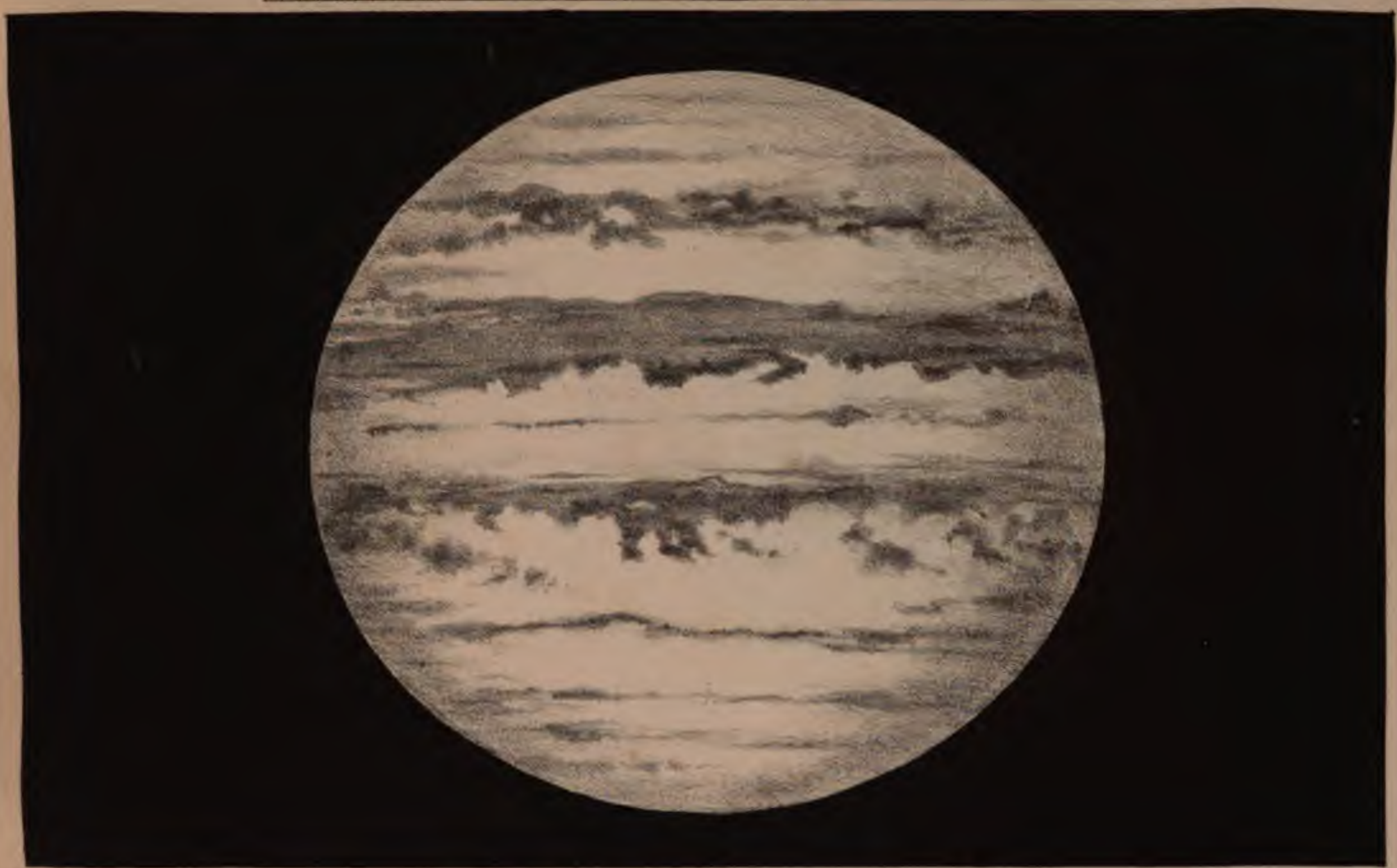
C.P.S. del.t J. Basire, lith.

The Cloud Horizon at Guajara as seen by moonlight: showing the summit of Grand Canary above the Clouds in the distance.

Phil. Trans. MDCCCLVIII. Plate XXXII.

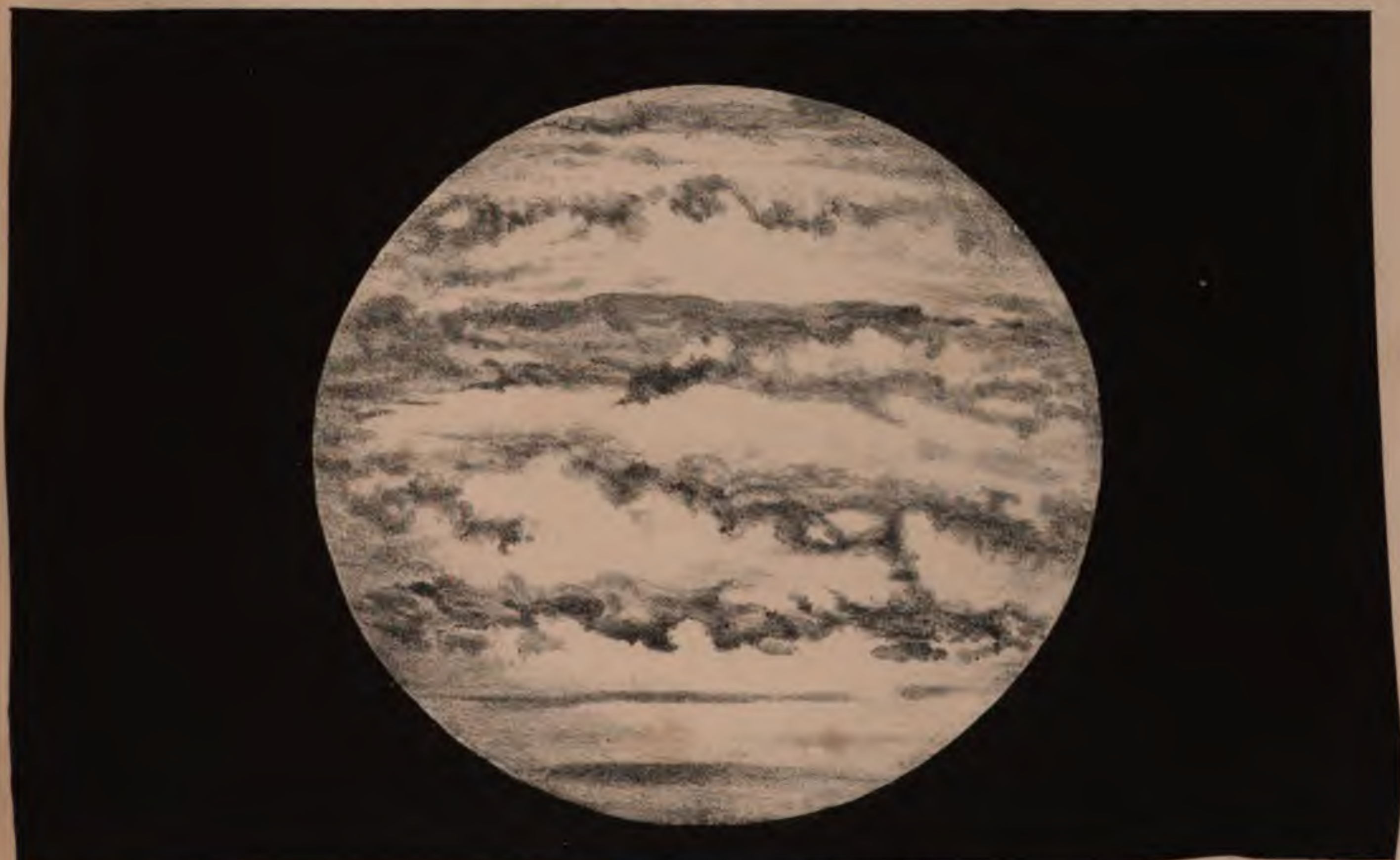
Scale of Seconds of Space

0 5 10 20 30 40″ 50″



ALTA VISTA STATION — JUPITER.

As seen in the Pattinson Equatorial with magnifying power 350 at 23h Sid. Time on September 4th 1856



C.P.S. del.t

J. Basire, lith.

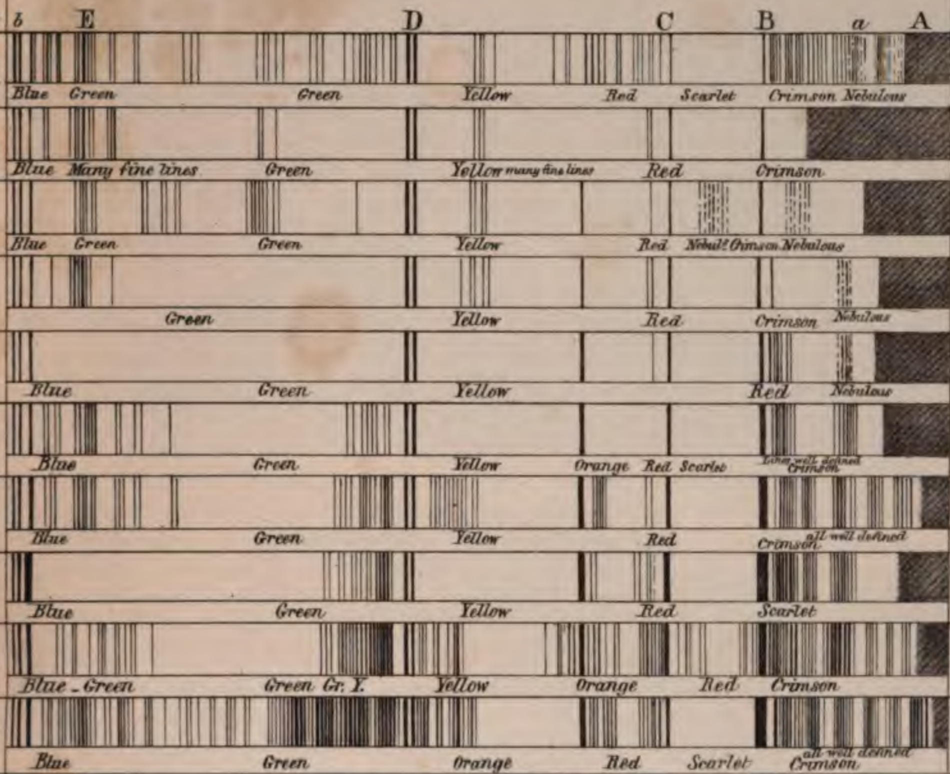
ALTA VISTA STATION — JUPITER.

At 23h 30m Sid. Time on September 5th 1856. Meridian 170° difference from drawing of Sept 4th.

TENERIFFE ASTRONOMICAL EXPERIMENT.

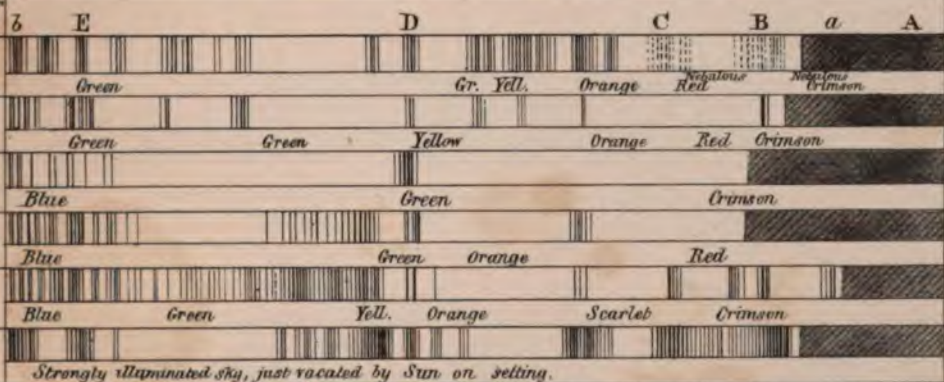
P.P. 1.

Lines in Red ends of sun-spectrums, direct and reflected.



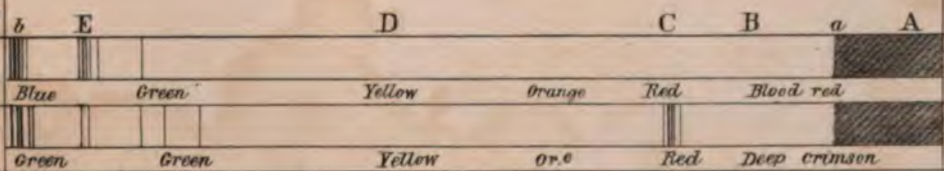
No. for Ref.	Spectrum	Day	Hour	Direct or Reflected	Alt. of Sun	Height of Station	Estd. Value
1	Blue Green Green Yellow Red Scarlet Crimson Nebulous	Septr. 23	h. 0 P.M.	D.	61°	feet 50	10
2	Blue Many fine lines Green Yellow many fine lines Red Crimson	Augt. 7	0 P.M.	R.	78	8903	4
3	Blue Green Green Yellow Red Nebul. Crimson Nebulous	Augt. 8	0.30 P.M.	R.	77	8903	7
4	Green Yellow Red Crimson Nebulous	Augt. 8	8.30 A.M.	R.	20	8903	5
5	Blue Green Yellow Red Nebulous	Augt. 9	5.30 A.M.	D.	5	8903	4
6	Blue Green Yellow Orange Red Scarlet Lines well defined Crimson	Augt. 9	P.M.	D.	23	8903	4
7	Blue Green Yellow Red Crimson all well defined	Augt. 9	P.M.	D.	1.0	8903	4
8	Blue Green Yellow Red Scarlet	Augt. 8	P.M.	D.	-0.1	8903	2
9	Blue - Green Green Gr. Y. Yellow Orange Red Crimson	Augt. 12	A.M.	D.	-0.5	8903	5
10	Blue Green Orange Red Scarlet all well defined Crimson	Augt. 9	P.M.	D.	-1.1	8903	4

Same of Sky-spectrums, all direct.



No. for ref.	Spectrum	Day	hour	Az.	Alt.	Height of Station	Estd. value
11	Green Gr. Yell. Orange Red Nebulous Nebulous Crimson	Septr. 23	h. 1 P.M.	N	48°	feet 50	5
12	Green Green Yellow Orange Red Crimson	Augt. 16	0 P.M.	S 10° E	7.5	8903	3
13	Blue Green Crimson	Septr. 12	4.30 P.M.	E	4.5	10702	2
14	Blue Green Orange Red	—	—	E	2.5	10702	2
15	Blue Green Yell. Orange Scarlet Crimson	—	—	E	6	10702	3
16	Strongly illuminated sky, just vacated by Sun on setting.	Augt. 9	P.M.	W	-1.1	8903	4

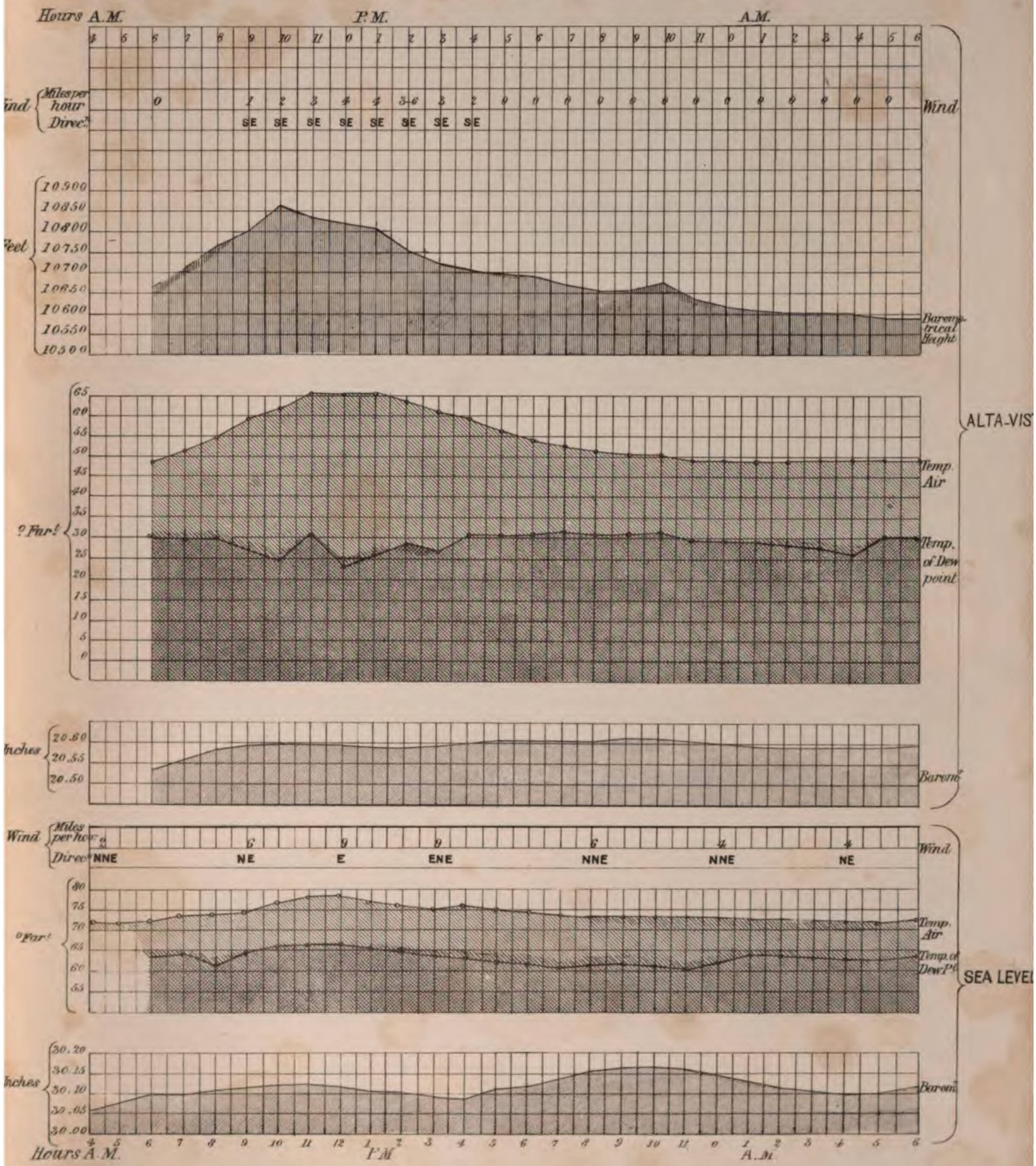
Same of Moon-spectrums, also direct.



No. for ref.	Spectrum	Day	hour	Az.	Alt.	Height of Station	Estd. value
17	Blue Green Yellow Orange Red Blood red	Augt. 13	9 P.M.	S	25°	feet 8903	1
18	Green Green Yellow Or.e Red Deep crimson	Augt. 15		S 20° E	38°	8903	3

J. Basire lith.

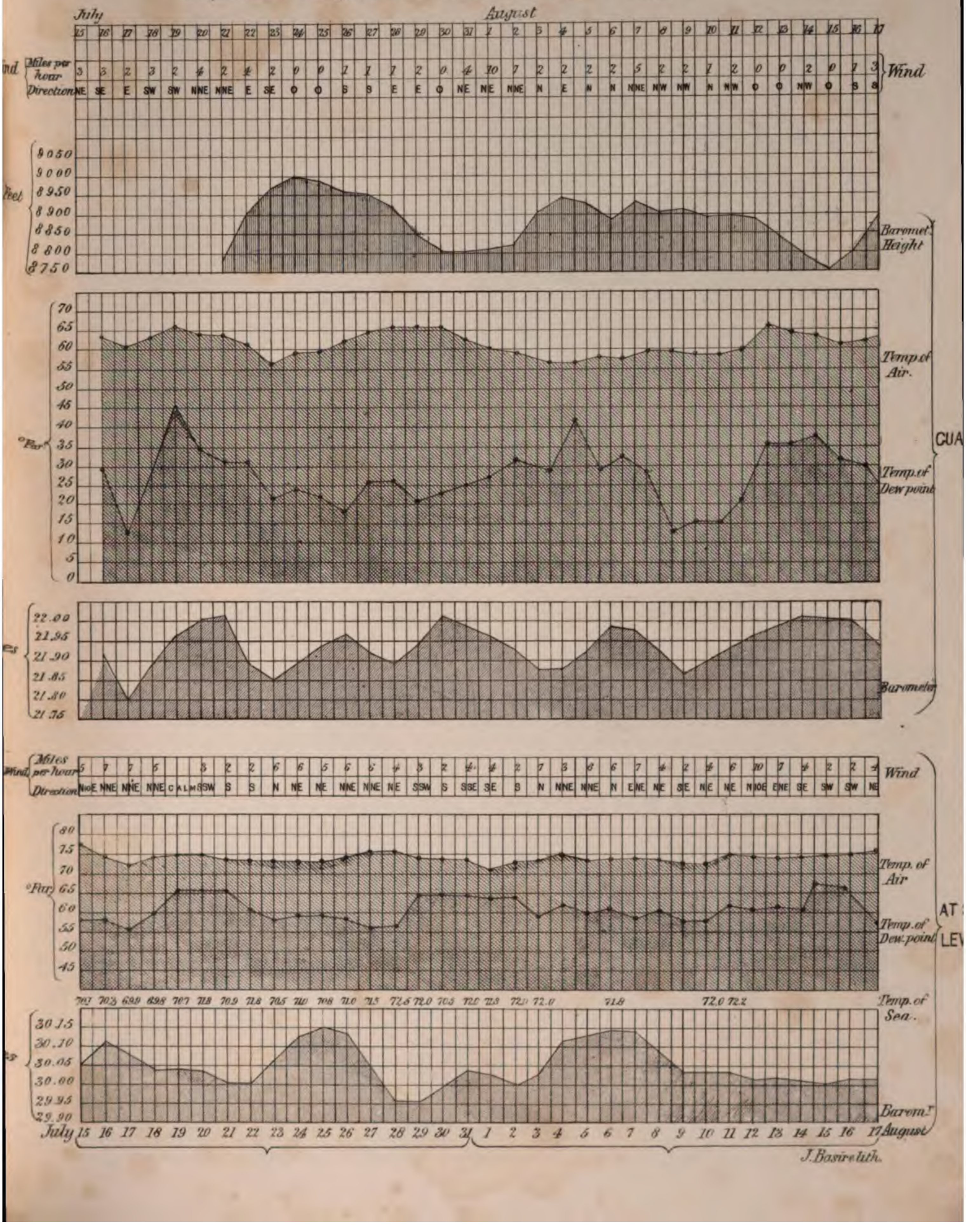
Comparison of hourly Variations at the Sea-level, and at Alta Vista on August 21st. M.P.2.



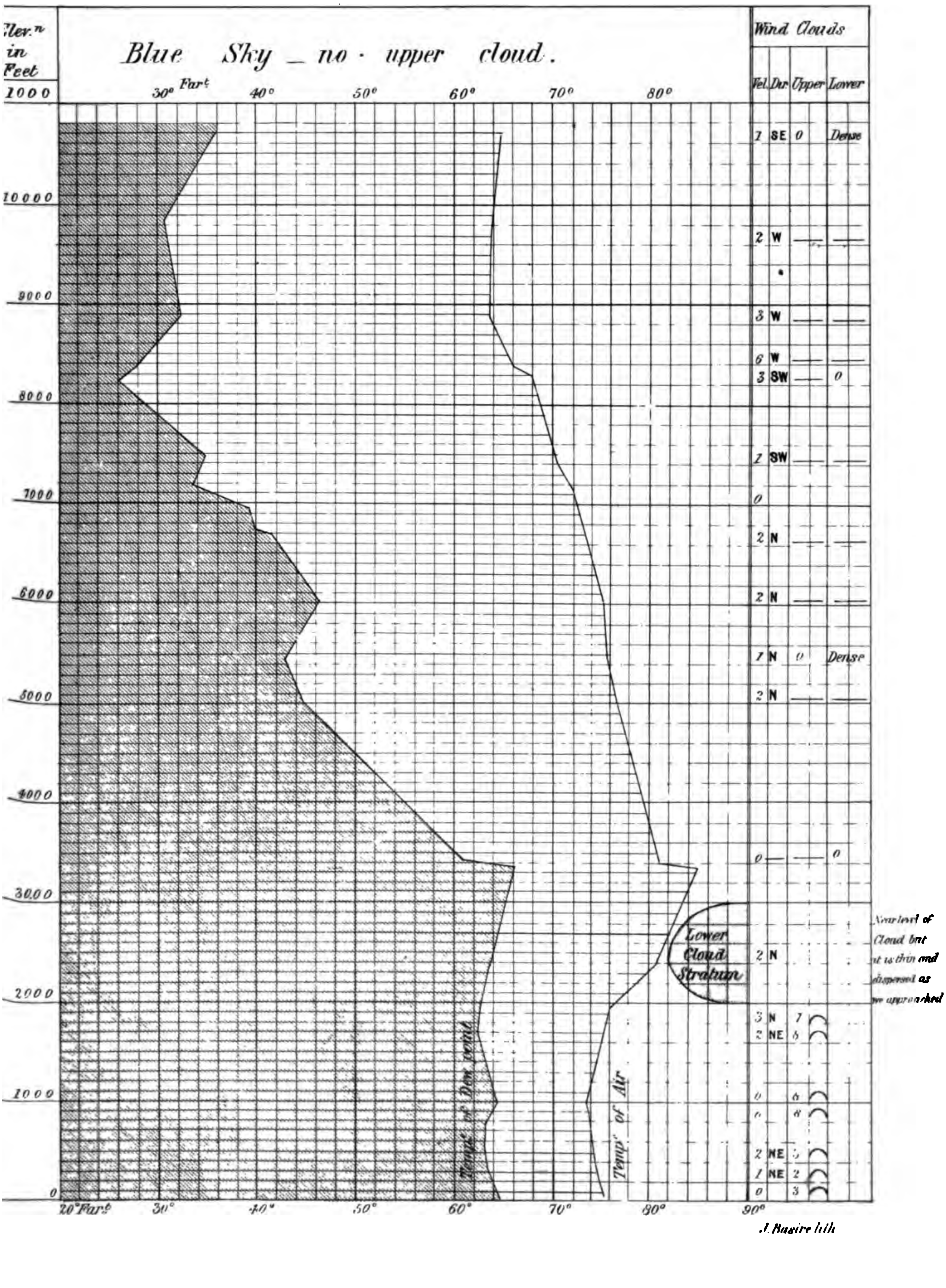
J. Basire lith.

Comparison of Daily Means at the Sea-level and at Guajara.

M.P. 3.

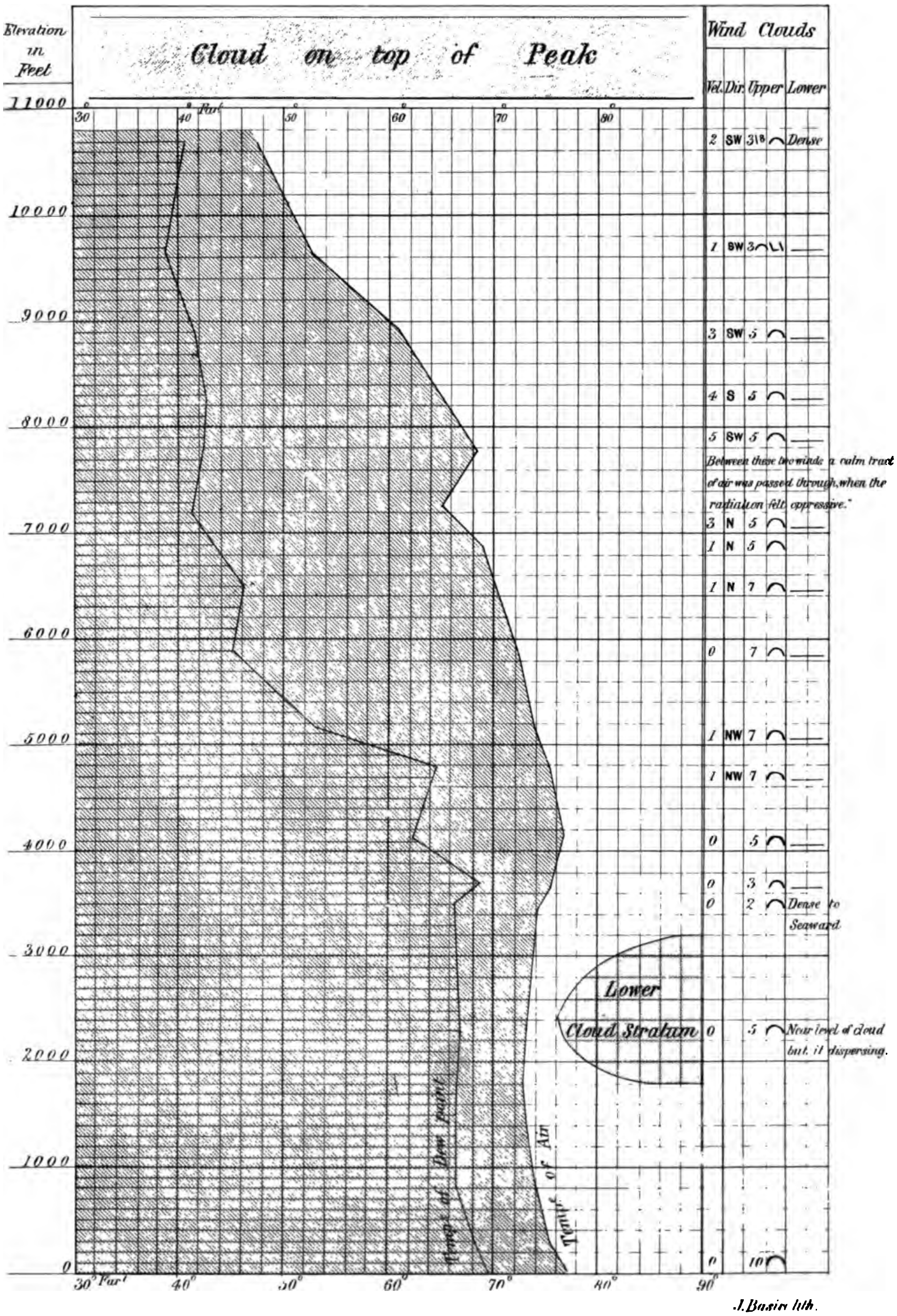


Meteorological descent from Alta Vista to Orotava 25th August 1856. M.P. 5.



J. Basire lith.

Meteorological ascent from Orotava to Alta Vista 30th August, 1856. M. P. 6.



J. Basire lith.

C. P. S., Phot. J. P. S., Pr.

THE ALTA-VISTA OBSERVATORY OF 1856,

AT A HEIGHT OF 10,702 FEET ABOVE THE SEA.

FROM AN ENLARGED CAMERA-COPY OF PHOTOGRAPH NO. 42, IN M.S. VOL. 10, OF TENERIFFE REPORT.

INDEX.